2

THE REFRACTIVE CHARACTER OF THE EYES OF MAMMALIA,

AND

THE ACTION OF MYOTICS ON THE ACCOMMODATION.

BY

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COLLEGE OF SURGEONS OF

LONDON:
PRINTED BY HARRISON AND SONS, ST. MARTIN'S LANE.
1886.

Reprinted from the Royal London Ophthalmic Hospital Reports
Vol. XI, Part II.

2

OF SURGEONS
24

THE REFRACTIVE CHARACTER OF THE EYES OF MAMMALIA.

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Although from time to time many incidental references to the refractive character of the eyes of mammalia have been made, we believe that hitherto a publication embodying the results of a systematic examination of the eyes of living animals has not appeared.

We therefore examined the eyes of a large number of living mammals, in most cases without the aid of any anæsthetic; the proceeding, however, has been in the highest degree difficult, and the results can only be regarded as approximate in character.

The general result has been fairly satisfactory, especially if it be regarded from an evolutionary standpoint.

Naturally we wished to estimate the refraction of the eyes in the visual axis, but as it is apparently impossible not only to ascertain whether there is an angle α in animals, but even to determine the direction of the visual axis, we simply estimated the refraction in an axis passing from the middle of the fundus through the centre of the cornea, that is, virtually in the optic axis. In the human eye it has been shown that the refraction at the optic disc differs from that at the yellow spot (7); in some animals (notably guinea-pigs) we also found marked differences between the disc and the centre of the fundus, and we have no hesitation in pronouncing the results obtained in these cases by estimation at the disc to be unreliable.

One of the greatest difficulties we experienced was to keep the eye of an animal fixed in one position even for a minute; but this was best overcome by carefully wrapping the animal in a cloth, to keep it warm, and then fixing the head firmly with the hand. Most of the work was done in a dark room, the only light entering the animal's eye proceeding from the ophthalmoscope mirror, and very often the animal quietly regarded the light for several minutes at a time.

Of the two objective methods at our disposal for estimating the degree of refraction of an eye, retinoscopy and the direct examination, we chose the former and practised it in the following manner. Whilst an assistant held the animal's head firmly, one of us from a distance of 1·5 to 2 meters threw the light by means of a concave mirror of 25 cm. f.d. into the eye, whilst the other held the trial lenses close to the cornea and at right angles to the direction in which the animal appeared to be looking. The estimation had to be frequently repeated before a satisfactory result was obtained. Estimation by the direct method is very difficult and unreliable, since estimation at the disc gives inaccurate results; if, as in the case of rabbits and guinea-pigs, there are neither blood-vessels nor tapetum, the method is impracticable. In those cases where it was possible we have endeavoured to corroborate by the direct method the results obtained by retinoscopy.

In the cases of the smaller animals we estimated the refraction both before and after the application of atropine, which presumably paralyses any accommodation they may possess.

Refraction of the Eyes of Rabbits.

We have examined the eyes of twenty-seven rabbits—in the majority of cases both before and after the use of atropine.

Before proceeding to analyse our results, we wish to state that we are at issue with Wolfskehl (1) on a matter of fact. The pupil of every one of the 54 rabbits' eyes we examined was oval, the long axis of the pupil being vertical. The difference between the diameter of the pupil in the vertical and in the horizontal meridian was never very great, and when dilated by atropine the pupil appeared to be round. Certainly he only refers to the examination of the eyes of two rabbits, and as he does not mention the variety to which they belonged, it is possible that they belonged to a class of rabbits which have round pupils. Yet he makes a general statement on the subject: "Ausserdem vermehrte ich die bereits bekannten Maasse von Kaninchenaugen durch einige eigene Messungen, um Vergleiche mit Augen, welche eine *stets** rund Pupille besitzen, anstellen zu können." He further states that Schelske (3) found "dass die Cornea des Kaninchenauges, das eine immer kreisrunde Pupille besitzt," &c. Whether in this subordinate sentence he is making a statement of his own or not we cannot say, but we have been unable to find any reference to a "kreisrunde Pupille" in Schelske's original article. We should not have referred to this matter were it not of great importance when viewed from a teleological standpoint.

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* The italics are ours.

THE EYES OF RABBITS.

Animal.		Results given by retinoscopy before the application of atropine, less 0·5 D.		Results given by retinoscopy after the application of atropine, less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.	
(1.) Adult domestic rabbit, albino	right eye	– 2 D.	0	– 2 D.	0	
	left eye	– 2 D.	+ 0·5 D.	– 2·5 D.	0	
(2.) Adult domestic black and white rabbit	right eye	..	..	+ 1·5 D.	+ 1·5 D.	
	left eye	..	..	+ 2 D.	+ 2 D.	
(3.) Adult domestic grey and white rabbit	right eye	+ 1 D.	+ 0·5 D.	+ 1 D.	+ 0·5 D.	
	left eye	+ 1 D.	+ 0·5 D.	+ 1 D.	+ 0·5 D.	
(4.) Adult domestic rabbit	right eye	+ 3 D.	+ 2 D.	+ 3 D.	+ 2 D.	
	left eye	+ 3 D.	+ 2 D.			
(5.) Adult domestic rabbit	right eye	+ 3 D.	+ 2·5 D.	+ 3 D.	+ 2·5 D.	
	left eye	+ 3·5 D.	+ 3 D.	+ 3 D.	+ 2·5 D.	
(6.) Adult domestic rabbit	right eye	+ 2·25 D.	+ 2·75 D.			This animal died before retinoscopy was practised.
	left eye	+ 2·5 D.	+ 3 D.			
(7.) Adult domestic brown rabbit	right eye	+ 1·5 D.	+ 2·5 D.	+ 2·5 D.	+ 2 D.	
	left eye	+ 2 D.	+ 1·5 D.	+ 1·5 D.	+ 1·5 D.	

THE EYES OF RABBITS—*continued.*

Animal.		Results given by retinoscopy before the application of atropine, less 0·5 D.		Results given by retinoscopy after the application of atropine, less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.	
(8.) Adult domestic rabbit	right eye	+ 1·5 D.	+ 1 D.	+ 1·5 D.	+ 1·5 D.	
	left eye	+ 1·5 D.	+ 1·5 D.	+ 1·5 D.	+ 1·5 D.	
(9.) Adult domestic brown and white rabbit	right eye	+ 2 D.	+ 3 D.	+ 2 D.	+ 3 D.	
	left eye	+ 2 D.	+ 3 D.	+ 2 D.	+ 3 D.	
(10.) Half-grown grey and white rabbit	right eye	+ 1·5 D.	+ 4 D.	+ 1·5 D.	+ 3·5 D.	
	left eye	+ 1·5 D.	+ 4 D.	+ 2 D.	+ 4 D.	
(11.) Half-grown brown and white domestic rabbit	right eye	+ 2 D.	+ 3 D.	+ 2 D.	+ 2·5 D.	
	left eye	+ 2 D.	+ 3 D.	+ 2 D.	+ 2·5 D.	
(12.) Adult brown and white domestic rabbit	right eye	− 2 D.	− 2·5 D.	− 2 D.	− 2 D.	
	left eye	− 1·5 D.	− 2 D.	− 1·5 D.	− 2 D.	
(13.) Adult white domestic rabbit	right eye	+ 2·5 D.	+ 4 D.	+ 2·5 D.	+ 3·5 D.	
	left eye	+ 2·5 D.	+ 4 D.	+ 2·5 D.	+ 3·25 D.	
(14.) Adult white domestic rabbit	right eye	+ 2·5 D.	+ 3·5 D.	+ 2·75 D.	+ 3·5 D.	
	left eye	+ 2·5 D.	+ 3·5 D.	+ 2·75 D.	+ 3·5 D.	

THE EYES OF RABBITS—*continued.*

Animal.		Results given by retinoscopy before the application of atropine, less 0·5 D.		Results given by retinoscopy after the application of atropine, less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.	
(15.) Adult white domestic rabbit	right eye	+ 1·5 D.	+ 2·25 D.	+ 1·25 D.	+ 2 D.	
	left eye	+ 1·5 D.	+ 3·5 D.	+ 1·5 D.	+ 3 D.	
(16.) Three-quarter grown white domestic rabbit	right eye	– 1·5 D.	+ 1·5 D.	– 1 D.	+ 1 D.	
	left eye	+ 0·25 D.	+ 1·5 D.	+ 0·25 D.	+ 1·5 D.	
(17.) Three-quarter grown black domestic rabbit	right eye	+ 3 D.	+ 6 D.	+ 2 D.	+ 5 D.	
	left eye	+ 3·5 D.	+ 5·5 D.	+ 2 D.	+ 5 D.	
(18.) Adult black and white domestic rabbit	right eye	+ 2 D.	+ 2 D.	+ 2 D.	+ 2 D.	
	left eye	+ 2 D.	+ 2 D.	+ 2 D.	+ 2 D.	
(19.) Half-grown brown and white rabbit	right eye	+ 3·5 D.	+ 3·5 D.	+ 3·5 D.	+ 3·5 D.	
	left eye	+ 2·5 D.	+ 3 D.	+ 2·5 D.	+ 3 D.	
(20.) Half-grown grey and white domestic rabbit	right eye	+ 1 D.	+ 1 D.	+ 1 D.	+ 1·5 D.	
	left eye	+ 0·5 D.	+ 0·5 D.	+ 1 D.	+ 1 D.	
(21.) Adult grey domestic rabbit	right eye	– 2 D.	0	0	+ 1 D.	
	left eye	– 2·5 D.	0	0	+ 1 D.	

THE EYES OF RABBITS—*continued.*

Animal.		Results given by retinoscopy before the application of atropine, less 0·5 D.		Results given by retinoscopy after the application of atropine, less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.	
(22.) Adult black and white domestic rabbit	right eye	0	+ 0·5 D.	0	+ 0·5 D.	
	left eye	– 0·5 D.	+ 0·5 D.	– 1 D.	+ 0·5 D.	
(23.) Adult grey domestic rabbit	right eye	+ 1·5 D.	+ 3·5 D.	+ 0·5 D.	+ 2·5 D.	
	left eye	+ 1·5 D.	+ 3·5 D.	+ 1·5 D.	+ 3 D.	
(24.) Adult grey domestic rabbit	right eye	+ 1·5 D.	+ 3·5 D.	+ 2 D.	+ 2 D.	
	left eye	+ 1 D.	+ 3 D.	+ 3 D.	+ 3 D.	
(25.) Adult grey domestic rabbit	right eye	+ 1·5 D.	+ 2·5 D.	+ 2·5 D.	+ 2·5 D.	
	left eye	+ 0·5 D.	+ 2 D.	+ 1·5 D.	+ 1·5 D.	
(26.) Adult grey domestic rabbit	right eye	+ 2 D.	+ 3 D.	+ 2·5 D.	+ 3 D.	
	left eye	+ 2 D.	+ 3 D.	+ 2·5 D.	+ 3 D.	
(27.) Adult sandy-coloured domestic rabbit	right eye	+ 1 D.	+ 1 D.	+ 1 D.	+ 2 D.	
	left eye	+ 1·5 D.	+ 1·5 D.	+ 1·5 D.	+ 1·5 D.	

Of the 52 eyes examined without any previous application of atropine, 36 were hypermetropic and astigmatic, 8 were hypermetropic only, 5 were myopic and astigmatic, whilst 3 were characterised by mixed astigmatism. If the hypermetropic and hypermetropic and astigmatic eyes be grouped together, the lesion of refraction was unsymmetrical as regards quality in only three cases.

Of the 51 eyes examined after the application of atropine had caused complete mydriasis, and presumably paralysis of any accommodation the rabbit may possess, 14 were hypermetropic, 31 were hypermetropic and astigmatic, 1 was myopic, 3 were myopic and astigmatic, whilst 2 were characterised by mixed astigmatism. If the hypermetropic and the hypermetropic and astigmatic eyes on the one hand, and the myopic, and myopic and astigmatic eyes on the other, be respectively grouped together, the lesion was unsymmetrical in quality in two animals only.

A comparison of the results obtained before and after the application of atropine shows that—

(1.) In 16 cases the refraction indicated was unaltered.

(2.) In 4 cases the astigmatism remained unaltered, but the total amount of hypermetropia was decreased.

(3.) In 1 case the hypermetropia was increased by 0·5 D.

(4.) In 1 case the astigmatism remained unaltered, and the myopia was increased by 0·5 D.

(5.) In the remaining cases the amount of astigmatism indicated before the application of atropine differed from that indicated after its use.

(*a.*) In 18 cases the difference was from 0·25 D to 0·75 D.

(*b.*) In 9 cases it amounted to from 1 D. to 2 D.

A survey of this table shows that rabbits have no latent hypermetropia, or that atropine does not paralyse their accommodation. Since atropine paralyses the pupillary muscle of the rabbit to much the same degree that it paralyses the human pupillary muscle, it seems difficult to believe that it does not affect their accommodation apparatus. The question, however, at once suggests itself, "Do rabbits use their accommodation to an appreciable extent?" If one notes (7) the refraction indicated by retinoscopy in the human eye, during an examination lasting even a few minutes, the degree indicated will be found to vary greatly owing to the activity of the accommodation apparatus. Yet we have watched rabbits' eyes for even an hour, and have never noticed any change. This would lead to the assumption that rabbits do not accommodate to any appreciable extent. We think it probable that their range of accommodation is very limited, and we cannot believe that their accommodation is sufficient to obviate the result of the hypermetropia or of the astigmatism which their eyes usually possess, even when they look at objects situated at an infinite distance from them. In other words, in few cases is a really perfect image formed on their retina.

Hirschberg (5) by means of the ophthalmoscope estimated the refraction at the optic disc of the eyes of rabbits (how many?), and states "dass die Kaninchen nicht bloss (wie die meisten Thiere) übersichtig, sondern auch nicht selten stark astigmatisch sind," and yet earlier he refers to "zum grossen Theil excavirte Sehnervenscheibe." He also makes the following statement: "Man versteht dass die optischen Bilder der Kaninchen- (Pferde-, Hunde-) Augen an Schärfe mit denen der Menschen nicht rivalisiren können, und dass diese Thiere wohl entschieden schlechter sehen als wir selber." Taking our table of the results indicated after the application of atropine as representing most accurately the refractive character of their eyes, it seems that 36 of the 51 eyes were astigmatic. In 13 of these 36 eyes the astigmatism was 0·5 D. or less, in 4 cases it was 0·75 D., whilst in the remaining 19 cases it varied from 1 D. to 3 D.; the total average amount of astigmatism was rather more than 1 D. The position of the two principal meridians in these astigmatic eyes was always vertical and horizontal, that is, in the direction of, and at right angles to, the long axis of the pupil. No matter in what position the rabbit be placed, it invariably endeavours to keep the long axis of the pupil vertical; if the animal's head be slowly rotated in a vertical plane, it will endeavour to rotate its eyes sufficiently to correct the deviation of its pupils from the vertical. This rotation can be exercised to the extent of about 90°. Its visual knowledge of the outer world is always gained whilst its pupil is maintained in the position referred to.

An examination of these 36 astigmatic eyes shows that the horizontal meridian was that in which the eye was least curved in 29 cases, and that these cases include the cases of myopic and mixed astigmatism, with one exception. In the remaining 7 cases in which the vertical was the least curved meridian, the astigmatism only exceeded 0·5 D. in 1 case. Since the great majority of the eyes were hypermetropic, it is evident that a slit-like pupil directed vertically would enable the animal to obtain the best vision with the least effort, especially if one assumes for the moment that the accommodation is used to correct the hypermetropia. Apart from the fact that, as already stated, this assumption seems to be unwarranted, there are other grave objections to this teleological view of the nature of the slit-like pupil; reference will be made to these later on.

Both Schelske (3) and Wolfskehl (1) seem to have been unable to find any great amount of corneal astigmatism in rabbits' eyes. The latter observer writes: "Es geht nämlich aus ihr (Schelske's Arbeit) hervor: 1. dass die Cornea des Kaninchenauges, das eine immer kreisrunde Pupille besitzt, einen nennenswerthen (regelmässigen) Hornhaut-astigmatismus überhaupt nicht besitzt, womit meine an zwei Kaninchenaugen vorgenommenen Messungen übereinstimmen." He made measurements of the eyes of rabbits before and after death, and says further:

"Es folgt 2. aus Schelke's Messungen, dass Augen, die im Leben keine oder nur geringe Asymmetrie zeigen, auch nach dem Tode keine oder nur eine 0·2 mm. nicht übersteigende Asymmetrie wahrnehmen lassen. Messungen, die ich selbst an einem Kaninchenauge angestellt habe, ergaben als Differenzen des senkrechten und horizontalen Meridians, lebend 0·032 mm., enucleirt 0·184 mm." Nevertheless he himself admits his measurements relate only to the corneal astigmatism, and remarks: "Ob diese Hornhautasymmetrie in den genannten Thieraugen nun wirklich Astigmatismus verursacht oder ob der Hornhautastigmatismus etwa durch Linsenastigmatismus ausgeglichen wird, darüber kann ich etwas Entscheidendes nicht beibringen."

We cannot, therefore, but think that our measurements of the refraction of the whole eye, made on docile, manageable animals with the precautions mentioned, and without the aid of any anæsthetic, represent very nearly the true refractive character of rabbits' eyes.

The Refractive Character of the Eyes of Guinea-pigs.

The results of the examination of twenty-seven guinea-pigs' eyes are noted below. Since these animals possess no tapetum, and their retinæ contain no blood-vessels, accurate estimation by the direct method is impossible. Sections of the optic disc often show a very deep physiological cup, the presence of which complicates retinoscopy and makes any estimation at that point by the direct method valueless.

Hirschberg (5) endeavoured to estimate the refraction of the eyes of guinea-pigs presumably by the direct method (how many he does not state), and apparently did not satisfy himself on the point (probably for the reason we have referred to); he makes the following rather indefinite statement:—"Der Astigmatismus des atropinisirten Auges ist sehr beträchtlich, so dass es kaum gelingt eine objective Refractionsmessung anzustellen. Doch möchte ich das Meerschweinchen mehr für kurzsichtig halten."

Guinea-pigs are not nearly so manageable as rabbits, and we do not think the quantitative results given below can be regarded as being more than approximate. Their pupils appear to be round, but if eserine be applied they become oval, the long axis of the oval being directed vertically. They endeavour to maintain the pupil in this position if their bodies are rotated by rotating the eyes in a compensating manner, but this rotation is not so extensive as in the case of rabbits.

THE EYES OF GUINEA-PIGS.

Animal.		Result given by retinoscopy before the application of atropine, less 0·5 D.		Result given by retinoscopy after the application of atropine, less 0·5 D.	
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.
(1.) Adult black guinea-pig	right eye	– 6·5 D.	– 5·5 D.	– 6·5 D.	– 6·5 D.
	left eye ..	– 5·5 D.	– 5·5 D.	– 6·5 D.	– 6·5 D.
(2.) Adult yellow guinea-pig	right eye	– 9·5 D.	– 6·5 D.	– 9·5 D.	– 6·5 D.
	left eye ..	– 8·5 D.	– 7·5 D.	– 8·5 D.	– 7·5 D.
(3.) Adult black guinea-pig	right eye	– 4·5 D.	– 7·5 D.		
	left eye ..	– 4·5 D.	– 5·5 D.		
(4.) Adult yellow guinea-pig	right eye	+ 1·5 D.	+ 3·5 D.	+ 3·5 D.	+ 5·5 D.
	left eye ..	+ 2·5 D.	+ 3·5 D.	+ 2·5 D.	+ 4·5 D.
(5.) Adult yellow and white guinea-pig	right eye	+ 0·5 D.	+ 4 D.	0	+ 3 D.
	left eye ..	+ 1 D.	+ 4 D.	+ 2 D.	+ 5 D.
(6.) Adult black and yellow guinea-pig	right eye	+ 2 D.	+ 4·5 D.	+ 2·5 D.	+ 5 D.
	left eye ..	+ 2 D.	+ 5 D.	+ 1·5 D.	+ 4·5 D.
(7.) Adult yellow and white guinea-pig	right eye	+ 0·5 D.	+ 4·5 D.	+ 1 D.	+ 4·5 D.
	left eye ..	+ 0·5 D.	+ 2·5 D.	+ 1 D.	+ 4 D.
(8.) Adult black guinea-pig	right eye	+ 0·5 D.	+ 5·5 D.	+ 0·5 D.	+ 5·5 D.
	left eye ..	+ 0·5 D.	+ 5·5 D.	+ 0·5 D.	+ 5·5 D.

THE EYES OF GUINEA-PIGS—*continued.*

Animal.		Result given by retinoscopy before the application of atropine, less 0·5 D.		Result given by retinoscopy after the application of atropine, less 0·5 D.	
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.
(9.) Adult black and yellow guinea-pig	right eye	+ 4·5 D.	+ 4·5 D.	+ 4·5 D.	+ 4·5 D.
	left eye . .	Nebulæ on cornea.			
(10.) Adult yellow and white guinea-pig	right eye	– 1·5 D.	+ 2·5 D.	0	+ 4·5 D.
	left eye . .	–10·5 D.	– 4·5 D.	– 10·5 D.	– 4·5 D.
(11.) Adult yellow and white guinea-pig	right eye	+ 2·5 D.	+ 6·5 D.	+ 2·5 D.	+ 5·5 D.
	left eye . .	Nebulæ.			
(12.) Adult black and white guinea-pig	right eye	+ 2·5 D.	+ 5·5 D.	+ 2·5 D.	+ 5·5 D.
	left eye . .	+ 0·5 D.	+ 5·5 D.	+ 0·5 D.	+ 5·5 D.
(13.) Adult black and white guinea-pig	right eye	+ 2·5 D.	+ 5·5 D.	+ 3·5 D.	+ 7·5 D.
	left eye . .	– 1·5 D.	+ 3·5 D.	+ 1·5 D.	+ 5·5 D.
(14.) Adult yellow guinea-pig	right eye	+ 6·5 D.	+11·5 D.	+ 6·5 D.	+ 9·5 D.
	left eye . .	+ 2·5 D.	+ 4·5 D.	+ 4·5 D.	+ 7 D.

The refraction of the eyes of (1) and (2) represents the myopia in the region of the optic disc. We estimated it purposely in that region, and we have eliminated these cases from subsequent calculation.

Before the application of atropine it appeared that 1 eye was hypermetropic, 16 were hypermetropic and astigmatic, 3 were myopic and astigmatic, whilst 2 were characterised by mixed astigmatism.

After the application of atropine it appeared that 1 was hypermetropic, 18 were hypermetropic and astigmatic, and 1 was myopic and astigmatic. The marked and erratic difference between the two sets of results point to (1) the irregularity of the animals' eyes, and (2) the relative inaccuracy of the method of examination. Still a survey of the results indicates either that these animals have no latent or manifest hypermetropia, and that the hypermetropia is not corrected by any accommodation they possess. It will be further noted that the departure from the normal type of eye is much greater than in the case of the eyes of rabbits. Whether this is to be accounted for by their greater domestication, and by the want of selection in breeding, we are unable to state.

If the results noted of the examination of the eyes under the influence of atropine be regarded as the most accurate statement of the refraction, it seems that the astigmatism varied from 2 D. to 6 D. (average 3·3 D.). The principal meridians have always been marked "vertical" and "horizontal," and they are approximately so, yet it is impossible to determine the normal position of the animal's head, and the direction of the principal meridians very often seemed respectively to coincide with, and to be at right angles to, the direction of the palpebral fissure. In every astigmatic eye the least curved meridian was the horizontal one. Since guinea-pigs possess an almost perfectly round pupil, it is evident that the astigmatism which their eyes usually exhibit must materially impair their vision. If then the slit-like pupil of the rabbit which has an astigmatism averaging a little more than 1 D. was developed to obviate the results of the astigmatism, how much more should the guinea-pig with an average astigmatism of 3·4 D. of a similar qualitative character require a slit-like pupil, and what becomes of the consideration of this pupil in the rabbit from a teleological standpoint? Yet it is evident that in the matter of optical construction the guinea-pig is inferior to the "so nahe verwandten" rabbit.

The Refractive Character of the Eyes of Mice.

The task of estimating the refractive character of the eyes of ordinary wild mice was certainly the most difficult we undertook. It was very difficult to tell in what direction the animal was looking, and it was quite impossible to keep the animal still.

In the following table we have placed on record the quantitative result obtained; but we should recommend that it be taken to indicate that the ten mice-eyes we qualitatively examined were hypermetropic, and that the hypermetropia was considerable in amount.

THE EYES OF MICE.

Animal.		Result given by retinoscopy without any application of atropine and less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	
(1.) Adult grey mouse ..	right eye ..	+ 7·5 D.	+ 7·5 D.	
	left eye ..	+ 3·5 D.	+ 3·5 D.	
(2.) Adult black mouse ..	right eye ..	+ 6·5 D.	+ 6·5 D.	The hypermetropia seemed to be a little greater in the horizontal than in the vertical meridian.
	left eye ..	+ 7·5 D.	+ 7·5 D.	
(3.) Adult grey mouse ..	right eye ..	+ 5·5 D.	+ 5·5 D.	Ditto.
	left eye ..	+ 5·5 D.	+ 5·5 D.	
(4.) Adult grey and white mouse ..	right eye ..	Hypermetropic		
	left eye ..	Hypermetropic		
(5.) Adult grey mouse ..	right eye ..	+ 4·5 D.	+ 4·5 D.	
	left eye ..	+ 4·5 D.	+ 4·5 D.	

This table simply shows that ten mouse's eyes were distinctly hypermetropic.

The Refractive Character of the Eyes of Rats.

The examination of the eyes of the five half-wild animals, the result of which is appended, was a little less difficult than that of the eyes of the mice.

Of the 10 eyes examined under the influence of atropine 5 were hypermetropic, 3 were hypermetropic and astigmatic, 1 was slightly myopic, whilst the remaining one was characterised by mixed astigmatism. It will be observed that in the majority of the cases the departure from the emmetropic ideal eye is great. In the four astigmatic eyes the least curved meridian was the horizontal; the pupil in all cases appeared to be round.

THE EYES OF RATS.

Animal.		Result given by retinoscopy before the application of atropine, less 0·5 D.		Result given by retinoscopy after the application of atropine, less 0·5 D.	
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.
(1.) Black and white adult rat	right eye	+ 10 D.		+ 9 D.	
	left eye	+ 10 D.		+ 9 D.	
(2.) White adult rat	right eye	..	..	− 1·5 D.	+ 1·5 D.
	left eye	..	..	+ 0·5 D.	+ 3·5 D.
(3.) Black and white half-grown rat	right eye	..	..	+ 8·5 D.	+ 8·5 D.
	left eye	..	..	+ 10·5 D.	+ 10·5 D.
(4.) White half-grown rat	right eye	..	..	+ 6·5 D.	+ 8·5 D.
	left eye	..	..	+ 3·5 D.	+ 6·5 D.
(5.) White half-grown rat	right eye	..	..	+ 1·5 D.	+ 1·5 D.
	left eye	..	..	+ 0·5 D.	+ 0·5 D.

The principal meridians have been marked vertical and horizontal, but these terms only approximately express their direction, since the animals' heads were never in any one position for more than a few seconds at a time.

The Refractive Character of the Eyes of Cows.

Of the 10 eyes examined 5 were hypermetropic, 4 were hypermetropic and astigmatic, and 1 was slightly myopic. In the four astigmatic eyes the meridian of least curvature was always horizontal. The astigmatism was in most of the cases slight, never exceeding 2 D.

As we were unable to apply atropine, it is just possible that these eyes appeared to be almost normal, because the accommodation was correcting the error of refraction. It is nevertheless noteworthy that in these eyes possessing a horizontally directed slit-like pupil, the astigmatism exhibited the same qualitative characters that is exhibited in the case of the guinea-pig, which possesses round pupils, and in the case of the rabbit which possesses a slit-like pupil directed vertically.

Wolfskehl (1) measured the corneal astigmatism of 11 calves' eyes after enucleation, and found that sometimes the most curved (7 cases), and sometimes the least curved, meridian (4 cases) was "in der Richtung der spaltförmigen Pupille." He calculated the astigmatism indicated, and found it to be equivalent to from 7 D. to 3·7 D.

Mönnich (6) found by calculation that a cow's eye, of which he had made a section, possessed a myopia of 1·707 D., and attributed the presence of this myopia to the fact that cattle are kept in stalls for the greater part of the year, and that consequently they only direct their vision to near objects.

We investigated the position of the horizontally directed slit-like pupil, when the animal's head was raised and depressed, and we found that the horizontal direction of the pupil was approximately maintained in both positions. The investigation, however, is a difficult one to carry out, as the cow does not lend itself readily to the required manipulation.

THE EYES OF COWS.

Animal.		Results given by retinoscopy before the application of atropine, less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	
(1.) Adult milch cow.......	right eye	+ 2·5 D.	+ 3·5 D.	
	left eye..	+ 2·5 D.	+ 4·5 D.	
(2.) Adult milch cow.......	right eye	Hypermetropic.		
	left eye..			
(3.) Adult milch cow.......	right eye	0	+ 0·5 D.	
	left eye..	+ 0·5 D.	+ 0·5 D.	
(4.) Adult milch cow.......	right eye	– 0·5 D.	– 0·5 D.	
	left eye..	+ 0·5 D.	+ 0·5 D.	
(5.) Adult milch cow.......	right eye	0	+ 0·5 D.	
	left eye..	+ 0·5 D.	+ 0·5 D.	

The principal meridians were in all cases at right angles to and in the same direction as the long axis of the pupil.

The Refractive Character of the Eyes of Horses.

Of the 6 horses' eyes we examined, 1 was emmetropic, 3 were hypermetropic and astigmatic, and 2 were characterised by very slight mixed astigmatism, that is practically emmetropic. The astigmatism only once equalled 1 D., and the horizontal was always the least curved meridian. Unless these animals corrected a greater lesion of refraction by accommodation—a highly improbable event—it would seem that their eyes were nearly emmetropic.

Hirschberg (5), examining horses' eyes by the direct method, seems to have found much astigmatism, for he writes:—"Im aufrechten Bilde erkennt man die deutliche Chromasie und den starken Astigmatismus des Pferdeauges;" and, further, "Aber auch an centralen Theilen des

Augengrundes, namentlich an den Punkten des Tapetums, ist der Astigmatismus des Pferdeauges deutlich zu erkennen."

Berlin (2) makes the following definite and important statement with reference to the eyes of horses:—"Die beiden bis jetz auf ihre Cardinalpunkte untersuchten Pferdeaugen von Matthiessen und dem Verfasser zeigen beide eine Hypermetropie. Im ersteren Falle ist dieselbe freilich eine sehr geringe, von 0·332 D., welche man etwa einer Emmetropie gleichstellen kann; im zweiten ist sie eine höhere, von ca. 1 Dioptrie," and, further, "Es werden ausserdem ophthalmoskopisch auch niedrigere Grade von Hypermetropie, wie in Matthiessen'schen Falle, Emmetropie, und ausnahmsweise sogar Myopie constatirt. Die stärkste vom Verfasser gefundene Myopie betrug 3 D." After referring to the irregular astigmatism of the lens, he refers to the regular astigmatism of the horse's cornea:—"Diese letztere scheint durchgängig eine ganz bestimmte Form zu haben, in der Art, dass der am wenigsten gekrümmte Hornhautmeridian mit der Längsrichtung der querovalen Pupille zusammenfällt, während der am stärksten gekrümmte Hornhautmeridian zu der Längsrichtung der Pupille annähernd senkrecht steht."

Berlin (4) published an account of the results of his examination of the eyes of domestic animals, but we have unfortunately only been able to find a reference to it. In this reference (Nagel's Jahresbericht) it is stated that he "hat verschiedene Hausthiere ophthalmoskopisch auf ihre Refraction untersucht, und sie durchschnittlich hypermetropisch gefunden." The highest grade of hypermetropia he found was 2·5 D., four times he found myopia in horses' eyes, the greatest amount being 8·5 D.

The normal direction of the pupil, the slit directed horizontally, is maintained with but slight deviation in both extreme elevation and depression of the head.

THE EYES OF HORSES.

Animal.		Result given by retinoscopy before the application of atropine, less 0·5 D.		Remarks.
		Vertical meridian.	Horizontal meridian.	
(1.) Adult horse	right eye...	Myopic	Slightly hypermetropic	
	left eye....	"	"	
(2.) Adult horse	right eye...	+ 0·5 D.	+ 1·5 D.	
	left eye....	0	0	
(3.) Adult horse	right eye...	0 D.	+ 0·5 D.	
	left eye....	0 D.	+ 0·5 D.	

The principal meridians were respectively at right angles to and in the direction of the long axis of the pupil.

The Refractive Character of the Eyes of Cats.

Of the 14 eyes examined before atropine was applied, 6 were hypermetropic, 4 were hypermetropic and astigmatic, 2 were slightly myopic, and 2 were myopic and astigmatic. The astigmatism exceeded 0·5 D. in 2 eyes only. Of the 12 eyes examined after the application of atropine, 2 were emmetropic, 6 were hypermetropic, 2 were hypermetropic and astigmatic, and 2 were myopic and astigmatic. In the 4 astigmatic eyes the horizontal was the meridian of greatest curvature, but the astigmatism never exceeded 0·75 D.

It will be seen that the cat's eye approaches very closely the emmetropic standard. What amount of accommodation they possess we do not know, but a cat whose pupils are completely paralysed with atropine can effect movements with perfect precision. We applied freely and frequently a strong atropine ointment to the eyes of a cat, and when the pupils were fully dilated, we allowed the animal to pursue a wild mouse. The cat moved with accuracy and celerity, and made a speedy capture.

Wolfskehl (1) measured the corneal astigmatism of cats, after they had been killed with chloroform, both whilst the eye remained in the corpse, and after it was enucleated. In one of the three eyes he thus examined, the two sets of results obtained seem to us to have differed materially. He found that the two principal meridians respectively corresponded to, and were at right angles to, the direction of the long axis of the pupil, that the astigmatism varied from 1·5 D. to 12·8 D., and that the least curved meridian was always vertical in direction. An astigmatism of 12 D. is enormous, and the fact that his measurements were exclusively corneal compels us to believe that there must have been some other correcting astigmatism in the animal's eye.

Hirschberg (5) writes :—" Das atropinisirte Auge einer getigerten Katze fand ich wenig hypermetropisch ;" and, later, " An diesem Punkte " (spots in the retina below the tapetum) " erkennt man leicht den Astigmatismus des atropinisirten Katzenauges," but he gives no further particulars.

Cats apparently (like rabbits) endeavour to keep the long axis of the pupil nearly vertical under all circumstances; owing to the situation of their eyes in the front of the head, the rotation of the eyes necessary to effect this result is not so often called for as in the case of the rabbit, and the movements of rotation, which can be observed when the cat's head is rotated to one side or the other, are not so extensive.

THE EYES OF CATS.

Animal.	Results given by retinoscopy before the application of atropine, less 0·5 D.		Result given by retinoscopy after the application of atropine, less 0·5 D.		Remarks.
	Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.	
(1.) Adult domestic cat .... { right eye.... left eye.....	Hypermetropic ,,		0 0	0 0	A small dose of chloroform administered to keep the animal quiet.
(2.) Adult domestic cat .... { right eye.... left eye.....	– 2 D. – 1·5 D.	– 2·5 D. – 2 D.	– 1·25 D. – 1·25 D.	– 2 D. – 2 D.	
(3.) Kitten æt. 3 months .... { right eye.... left eye.....	+ 0·5 D. + 0·5 D.	+ 2 D. + 2 D.	+ 2 5 D. + 2·5 D.	approximately ,,	
(4.) Kitten æt. 3 months..... { right eye.... left eye.....	+ 0·5 D. + 0·5 D.	+ 1 D. + 1 D.	+ 1·5 D. + 1·5 D.	,, ,,	
(5.) Kitten æt. 2 months..... { right eye.... left eye.....	+ 0·5 D. + 1 D.	+ 0·5 D. + 1 D.	+ 1 D. + 1·5 D.	+ 0·5 D. + 1 D.	
(6.) Adult tabby cat .... { right eye.... left eye.....	Slightly myopic Myopic	Slightly myopic Myopic	+ 0·5 D. + 0·5 D.	+ 0·5 D. + 0·5 D.	
(7.) Adult tabby cat .... { right eye.... left eye.....	+ 1 D. + 1 D.	+ 1 D. + 1 D.			

The principal meridians in the astigmatic eyes were in the direction of and at right angles to the direction of the long axis of the pupil.

The Refractive Character of the Eyes of Dogs.

It will be seen that the eyes of the dogs we examined were practically emmetropic.

Hirschberg (5), in referring to the results of his examination of the eyes of dogs by the direct method, writes: "der Astigmatismus ist nicht bloss an Sehnerven, sondern an dem ganzen Gefässbaum der Retina zu erkennen," but again refrains from giving particulars.

THE EYES OF DOGS.

Animal.		Results given by retinoscopy before the application of atropine, less 0·5 D.		Result given by retinoscopy after the application of atropine, less 0·5 D.	
		Vertical meridian.	Horizontal meridian.	Vertical meridian.	Horizontal meridian.
(1.) Poodle aged 3 years...	right eye..	+ 0·5 D.	+ 0·5 D.	+ 0·5 D.	0
	left eye...	+ 0·5 D.	+ 0·5 D.	+ 0·5 D.	0
(2.) Russian greyhound....	right eye..	Slightly myopic.			
	left eye...	,,			
(3.) Russian greyhound....	right eye..	Slightly hypermetropic.			
	left eye...	,,			

As we felt that an objection might be raised to conclusions based only on the results already given, on the ground that the animals were domesticated, we visited Mr. Jamrach's establishment, and made a qualitative examination of the eyes of a number of recently caught wild animals.

Deer.—Siki Deer (Persia), emmetropic both eyes; Cervus Porcinus (2), each hypermetropic both eyes; Black Bock (East Indies) (2), each hypermetropic both eyes.

Jackal.—Hypermetropic in both eyes.

Peccary.—Hypermetropic in both eyes.

Jeanette Cat (South America).—Hypermetropic in both eyes.

Paradoxus Cat (East Indies) (2).—Each hypermetropic in both eyes.

Australian Native Cat.—Hypermetropic in both eyes.

Mongoose.—Hypermetropic in both eyes.

Hyæna (2).—Hypermetropic in all three eyes (one animal had one eye destroyed).

Opossum.—Hypermetropic in both eyes.

Porcupine.—Hypermetropic in both eyes.

Monkeys (11 animals).—Two were myopic in both eyes, and nine were hypermetropic in both eyes.

Conclusions.

An examination of the results obtained by us shows that of the 185 eyes examined—

(1). 24 were emmetropic.

(2). 145 were hypermetropic, or hypermetropic and astigmatic.

(3). 13 were myopic, or myopic and astigmatic.

(4.) 3 were characterised by mixed astigmatism.

All eyes with a hypermetropia, myopia, or simple astigmatism, not exceeding 0·5 D, we have considered to be emmetropic.

It will be seen that about 7 per cent. of the eyes were myopic. Now it has been shown that myopia is essentially a disease engendered by sedentary habits, and therefore by civilisation, but the comparatively large percentage of myopic eyes we have discovered in animals seems to indicate the existence of another productive factor; for we cannot suppose that exercise of the accommodation apparatus influenced the production of this myopia.

Hirschberg (5) writes: "Ich will beiläufig bemerken dass vom teleologischen Standpunkt aus, beim Gegebensein der positiven Accommodation durch willkürlich angeregte Verdickung der Krystallinse, das axenkurze, also hypermetropische Auge am zweckmässigen erscheint." The truth of this statement no one can doubt if they regard the matter in the abstract, but we simply ask, "What particle of evidence is there that the domestic mammals use their accommodation to any appreciable extent?" It is absurd to suppose that they possess an apparatus capable of overcoming eight or even four diopters of hypermetropia, and so far we have failed to satisfy ourselves that they can overcome the lower grades. We are, however, at present engaged in minutely investigating the matter.

Whilst realising fully the danger of analysing too thoroughly figures which must be approximate in their signification, yet a general survey of those figures shows that as an optical instrument the eye of the horse, cow, cat, and rabbit, is superior to that of the rat, mouse, and guinea-pig.

Is this to be regarded as the result of the selective breeding of the former animals or not? It is at least reasonable to suppose that animals possessing very atypical eyes would often possess other qualities which would render them unfit for breeding purposes; and further that the careful feeding and other attention the domestic animals receive would react favourably on the development of so important an organ.

It will be noticed that we quantitatively examined 76 astigmatic eyes, and that in only 13 of these cases was the horizontal the meridian of greatest curvature. In only 3 of these 13 cases did the astigmatism exceed 0·5 D.; and on these 3 occasions it equalled 1 D. 0·75 D. and 0·75 D. respectively. Although in many of the cases of the opposite group the astigmatism did not exceed 0·5 D., yet that group includes all the cases of severe astigmatism, whether in myopic or hypermetropic eyes. In other words, as the result of our investigation of astigmatic eyes in animals, both hypermetropic and myopic, we find that in the great majority of cases, and in all severe cases, the horizontal is the least curved meridian, and we estimated the astigmatism of the whole eye, and not that of the cornea only. In the human eye this is also the most common form of astigmatism, but since we found a similar condition in the eyes of animals with round pupils, with vertically directed slit-like pupils, and with horizontally directed slit-like pupils, it seems to be necessary to seek for some widespread cause to explain its existence.

The usual form of an astigmatic eye—a vertically-flattened sphere—is the shape that a soft ill-supported sphere would assume by reason of its own weight. When such a sphere is acted upon by four muscles vertically and by only two horizontally, leaving aside any influence the lids may exert, it is readily conceivable that a weakly-formed sclerotic and cornea should assume the astigmatic shape. Once formed, this shape would have a tendency to be inherited, especially in domestic animals, amongst whom the law of the survival of the fittest does not obtain, at least as regards the eyes. In albino rabbits, which do not admit of much crossing, this defect was always marked, the astigmatism in our cases averaging 1·275 D.

On only one point, however, is the evidence decided and convincing; the principal meridians of the astigmatic eye are always in the direction of and at right angles to the direction of the long axis of the pupil, to this extent only does this evidence justify the consideration of the matter from a teleological standpoint. Were the slit-like pupil developed to obviate the evil results of the astigmatism, we should expect to find that the meridian of least curvature in myopic, and of greatest curvature in hypermetropic eyes, corresponded in direction with the long axis of the pupil. One would also certainly expect that animals with round pupils should not possess very astigmatic eyes. Yet every one of these requirements is unsatisfied, and we find throughout that the optical construction of these eyes evinces the existence of some general developmental agency which pays little regard to the *existing* shape of the pupil.

We feel that we are quite unable in the present state of our knowledge to conjecture the mode of origin, or even the possible purpose of this slit-like pupil, but we think that the evidence adduced indicates the probability of that explanation being obtained from a developmental and not from a teleological standpoint.

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THE ACTION OF MYOTICS ON THE ACCOMMODATION.

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THE ACTION OF ESERINE AND PILOCARPINE ON THE ACCOMMODATION.

IN the English edition of Donders' (1) classical work there occurs at p. 613 a reference to the increased range of accommodation produced by the application of a solution of Calabar bean to the eye. In this paper we have endeavoured to throw some light on the nature of this and of other changes in the accommodative apparatus which follow the application of eserine and pilocarpine to the eye.

I.—*The Action of Eserine.*

Method of Investigation.—In our investigations we have used a pink aqueous solution of eserine of 0·5 or 1 per cent. in strength. In the following tables where the application is marked "moderate" we dropped three or four drops of the solution into the lower conjunctival sac, whilst the lid was held away from the globe for half a minute or longer, so that the tears should not wash the drug away. In the cases where the term "profuse" is used this application was repeated at the end of two minutes.

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* To Mr. E. F. Herroun, of King's College, we are greatly indebted for several of the calculations embodied in this paper, and we desire to record our thanks to him for the assistance he has kindly given us from time to time.

Duquesnel (10) states that the colouring matter separated from a red solution of eserine does not act as a myotic and that old solutions of eserine should not be used; but that a neutral sulphate of eserine, which dissolves readily, should be kept in powder and dissolved only when about to be used. Again de Wecker (29) refers to this red colour and says that it develops twenty-four hours after the solution is made. Adolph Weber (17), however, seemed to think that the change of colour was not of much importance, for he refers to a change of colour, which both Merck's (Darmstadt) and Vée's (Paris) eserine undergo if kept, and he also says that the red colour in Vée's preparation is darker than in Merck's. Our pink solution had apparently always acted with great vigour, but in order to test the point, we applied to the same eye at different times, but as far as possible in the same manner, a freshly prepared colourless solution of eserine and the pink coloured one, and then compared the results; there appeared to be very little difference between them, if anything the coloured solution appeared to act less strongly than the colourless. We have therefore concluded that this inert colouring matter was not formed in sufficient quantity to interfere with the activity of our coloured solution.

Before applying the drug we ascertained the near point by the wire optometer. (Donders (1), p. 34.) In the case of myopes we also measured the far point with this instrument, but in the case of emmetropes and hypermetropes we ascertained the position of the far point by means of Snellen's test types at 6 M., and of spherical lenses. The optometer was held against a light background illuminated as far as possible to the same extent throughout the entire experiment. The diameter of the pupil was ascertained by means of an ordinary pupilometer, whilst the patient looked in the distance. After completing these measurements the eserine solution was applied either "moderately" or "profusely," and the far and near points and the diameter of the pupil were ascertained at regular intervals for from 80 minutes to several hours. When the far point in the case of hypermetropes and emmetropes was less than 2 M. distant we usually estimated its position with the optometer so long as it remained within that distance.

In the case of old people the estimation of the far point by the optometer is usually unsatisfactory, probably on account of their diminished acuity of vision. In most of the cases the eye was examined daily for several days after the application of the drug. We have always taken the measurements for the near and

Case I.—C. P., æt. 19. *Right Eye.* V. = $\frac{6}{6}$. Hm. 1 D.

Time.	Pupil.	P.P.		P.R.	
		Vertical.	Horizontal	Vertical.	Horizontal.
Before application	3·5 mm.	9 cm.	9 cm.	−100 cm.	−100 cm.
After application—					
3 minutes	3·5	8·5	8·5	−100	−100
7 ,, ...	3	6·75	6·75	23	23
12 ,, ...	2·5	5·5	7	27	60
15 ,, ...	2	5	4·5	25	22·5
20 ,, ...	1·5	4	4	23	23
26 ,, ...	1·75	5	4·5	28	33
30 ,, ...	1·5	4·5	4·5	37	44·5
36 ,, ...	2	5	5·5	76	85
42 ,, ...	2	5	5	150	
54 ,, ...	2	5	5		
57 ,, ...	2	5	5		
72 ,, ...	2	5	5		
102 ,, ...	2	5·5	5·5		
132 ,, ...	2	6	6		
157 ,, ...	..	5·5	5·5		
252 ,, ...	..	6	7		
312 ,, ...	..	7	7		
372 ,, ...	..	7	7		
432 ,, ...	..	7	7		
552 ,, ...	..	7·5	7		
24 hours	*Still contracted*	9 cm.	9 cm.		
48 hours	*Complete recovery*				

far points from the outer canthus, as it is impossible to follow the plan of measuring from a point situated at 7 mm. behind the cornea. Since absolute precision is not to be attained where the subjective element is brought into play, we have endeavoured to eliminate any errors by making numerous observations and by paying attention to the relative rather than to the absolute factors.

Case I. In this eye eserine caused—

(1.) An approximation of the far point, which reached its maximum at the 7th minute, and which disappeared in from 40 to 50 minutes. The maximum approximation was represented by 5·35 D.

(2.) An approximation of the near point, which began at the 3rd minute, reached its maximum in 20 minutes, and remained to a material extent for more than 9 hours. The maximum approximation was represented by 13·89 D.

(3.) A contraction of the pupil which began at the 7th minute, reached its maximum at the 20th minute, and remained for more than 24 hours.

(4.) An increase in the range of accommodation, preceded during the first 7 minutes by a decrease of 1·64 D. The maximum increase occurred at the 54th minute, but the range remained materially increased during the following 8 hours. This increase at its maximum amounted to 8·89 D.; that is, the range was changed from its normal 12·11 D. to 21 D.

It will be noticed that measurements of the far and near points in the vertical and horizontal meridians gave different results during the first 36 minutes of the observation. As it is evident that measurements cannot be made in the two meridians at the same time, and as eserine causes violent clonic spasms of the accommodative apparatus, it is improbable that these differences really represent any astigmatism. (*See* Chart.)

CASE II.—C. P., æt. 19. *Left Eye.* V. = $\frac{6}{6}$. Hm. 1 D. Moderate Application.

Time.	Pupil.	P.P.		P.R.	
		Vertical.	Horizontal.	Vertical.	Horizontal.
Before application	3·5 mm.	9 cm.	9 cm.	−100 cm.	−100 cm.
After application—					
3 minutes	3·5	7	7		
7 „	3	6·5	6·5	25	25
12 „	2·5	4·5	4	18	16
15 „	2	4·5	5	19	15·5
20 „	1·5	4·5	4·5	18	17
26 „	1·75	5	4·5	24	17
30 „	1·5	4·5	4·5	37	35
36 „	1·5	5	5	81	87
42 „	2	4·75	4·75		
54 „	2	4·75	4·75		
57 „	2	5	5		
72 „	2	5	5		
102 „	2	5·5	5·5		
132 „	2	5·5	5·5		
157 „	2	5	5		
252 „	2	6	7		
312 „	..	7	6		
372 „	..	7	7		
432 „	..	7	7·5		
552 „	..	7·5	7·5		
24 hours	..	9	9		
48 hours	Recovery of pupil.				

In this eye eserine caused—

(1.) An approximation of the far point, which began at the 7th minute, reached its maximum at the 12th minute, and disappeared in 42 minutes. The maximum approximation was represented by 6·9 D.

(2.) An approximation of the near point, which began at the 3rd minute, reached its maximum at the 12th minute, and remained to a material extent for more than 9 hours. The maximum approximation was represented by 12·45 D.

(3.) A contraction of the pupil which began at the 7th minute, reached its maximum at the 20th minute, and remained for more than 24 hours.

(4.) An increase in the range of accommodation, preceded by a decrease of 0·73 D. during the first 7 minutes. The maximum increase occurred at the 42nd minute, and the range remained materially increased during the following 8 hours. This increase at its maximum amounted to 9·94 D.; that is, the range was changed from 12·11 D. (normal) to 22·05 D.

CASE III.—J. W. B., æt. 23. *Left Eye.* V. = $\frac{6}{6}$. Hm. 0·5.

Moderate Application. Observations in Vertical Meridian only.

Time.	Pupil.	P.P.	P.R.
Before application ...	3 mm.	11 cm.	−200
After application—			
5 minutes	3	9·5	−200
10 "	3	8·5	100
15 "	2·5	8	15
20 "	2	7·5	16
25 "	2	7·5	52
30 "	2	7·5	61
35 "	2	7·5	150
40 "	2	8	−200
45 "	2	8	−200
55 "	2	7·5	−200
75 "	2	8	−200

The near point returned to its normal position within 8 hours, but the pupil remained contracted for more than 24 hours. It had recovered completely within 48 hours.

In this case eserine caused—

(1.) An approximation of the far point, which began at the 10th minute, reached its maximum in 15 minutes, and disappeared in 40 minutes. The maximum approximation was equivalent to 7·17 D.

(2.) An approximation of the near point, which began at the 5th minute and reached its maximum in 20 minutes. The near point remained greatly approximated for 75 minutes, and returned to its normal position in 8 hours. The maximum approximation was equivalent to 4·24 D.

(3.) A contraction of the pupil which began at the 15th minute, reached its maximum at the 20th minute, and remained for 24 hours.

(4.) An increase in the range of accommodation, interrupted between the 10th and 25th minutes by a decrease, which at its maximum was equivalent to 3·76 D.; that is, to more than one-third of the normal range (9·59 D.). The maximum increase occurred at the 55th minute, and was equivalent to 4·24 D., that is, to less than half the normal range, so that the total range at this time was 13·83 D. The increase disappeared within 8 hours.

Case IV.—A. S., æt. 17. *Right Eye.* Observations in Vertical Meridian only. Moderate Application.

Time.	Pupil.	P.P.	P.R.
Before application . . .	8 mm.	9 ·5 cm.	22 cm.
After application—			
5 minutes	7	9	20
10 "	5 ·5	9 ·5	15 ·5
15 "	4	7	15
20 "	2 ·5	7	13
25 "	2	5	13
30 "	2	5 ·5	16
35 "	2	5 ·5	18
40 "	2	5 ·5	22
45 "	2	5 ·5	22

In this case the application of eserine caused—

(1.) An approximation of the far point, which began at the 5th minute, reached its maximum at the 20th minute, and disappeared at the 40th minute. The maximum approximation was equivalent to 3·15 D.

(2.) An approximation of the near point, which began at the 5th minute, reached its maximum at the 25th minute, and at that time was equivalent to 9·47 D. This approximation remained to nearly the same extent at the 45th minute, when the far point had receded to its normal position.

(3.) A contraction of the pupil, which began at the 5th minute, reached its maximum at the 25th minute, and remained in this condition at the 45th minute, when the observations were discontinued.

(4.) An increase in the range of accommodation, preceded in the first 10 minutes by a decrease, which at its maximum was 1·91 D.; that is, one-third of the normal range (5·98 D.). The maximum increase occurred at the 40th minute, and was equivalent to 7·56 D.; that is, to more than the normal range; so that at this time the total range was 13·54 D. (*See* Chart.)

CASE V.—B. T., æt. 17. V. = $\frac{6}{6}$ − 1 D. Observations in Vertical Meridian only. Profuse Application.

Time.	Pupil.	P.P.	P.R.
Before application ...	5 mm.	10 cm.	75 cm.
After application—			
5 minutes	5	9·5	75
10 ,, ...	3	6	16
15 ,, ...	2	6·5	10
20 ,, ...	2	6	12
25 ,, ...	2	6·5	12·5
30 ,, ...	2	7	12·5
35 ,, ...	2	6·5	12·5
40 ,, ...	2	6·5	12·5
45 ,, ...	2	5·5	14
50 ,, ...	2	6	14
55 ,, ...	2	5·5	14
60 ,, ...	2	5	14
65 ,, ...	2	6	41
70 ,, ...	2	6	50
75 ,, ...	2	6	70
80 ,, ...	2	6	100
85 ,, ...	2	6	100

In this case the application of eserine caused—

(1.) An approximation of the far point, which began at the 10th minute, reached its maximum at the 15th minute, and disappeared at the 80th. The maximum approximation was equivalent to 8·67 D.

(2.) An approximation of the near point, which began at the 5th minute, reached its maximum at the 60th minute, and at that time was equivalent to 10 D. This approximation remained to a considerable extent at the 85th minute, when the far point had receded beyond the point it occupied previous to the instillation.

(3.) A contraction of the pupil, which began at the 10th minute, reached its maximum at the 15th minute, and remained in this condition at the 85th minute, when the observation was discontinued.

(4.) An increase in the range of accommodation, interrupted between the 10th and 45th minutes by a considerable and irregular decrease, which at its maximum at the 15th minute was 3·28 D.; that is, less than half the normal range (8·67 D.). The maximum increase occurred at the 80th minute, and was 7 D.; that is, nearly equal to the normal range, which at this time was increased to 15·67 D.

CASE VI.—W. L., æt. 32. $V. = \frac{6}{6}\ \bar{c}\ \frac{-4\text{ D. sph.}}{-1\text{ D. cyl.}}$. Moderate Application. Measurements in both Meridians.

Time.	Pupil.	P.P.		P.R.	
		Vertical.	Horizontal.	Vertical.	Horizontal.
Before application	3·5 mm.	9·5 cm.	9·5 cm.	20 cm.	18 cm.
After application—					
5 minutes	3·5	7	7	16	16
10 "	3·5	7	7	15	15
15 "	2·5	7	7	12	12
20 "	2	6·5	6·5	12	12
25 "	1·5	6·5	6·5	10	12
30 "	2	7	7	16	13
35 "	1·5	7	7	16	16
45 "	1·5	7	7	20	18

In this case the application of eserine caused—

(1.) An approximation of the far point, which began at the 5th minute, reached its maximum at the 25th minute, and had disappeared at the 45th. The maximum approximation was equivalent to 3·89 D.

(2.) An approximation of the near point, which began at the 5th minute, reached its maximum at the 20th minute, and at that time was equivalent to 4·86 D. This approximation remained to nearly the same extent at the 45th minute, when the observations were discontinued and the far point had receded to its original position.

(3.) A contraction of the pupil, which began at the 15th minute, reached its maximum at the 25th minute, and remained in this condition at the 45th minute.

(4.) An increase in the range of accommodation, which was at its maximum at the 45th minute, that is, when the far point had completely receded, and which at this time was equivalent to 3·76 D., or more than half the normal range (5·25 D.), so that the total range was then 9·01 D.

It will be observed that measurements of the near point in both meridians gave in this case the same results throughout, whereas in the case of the far point slight differences are noticeable. For reasons previously referred to (p. 133) we feel inclined to regard these observations as worthless.

Summary.

A 0·5 or 1 per cent. solution of sulphate of eserine applied moderately or profusely to these healthy emmetropic and ametropic eyes caused—

(1.) An approximation of the far point, which began from the 5th to the 10th minute, reached its maximum from the 7th to the 25th minute, and disappeared from the 40th to the 80th minute. The maximum approximation was equivalent to between 3·15 D. and 8·67 D.

(2.) An approximation of the near point, which began from the 3rd to the 5th minute, reached its maximum from the 12th to the 60th minute, and disappeared in from 8 to 9 hours. The maximum approximation was equivalent to between 4·24 D. and 13·89 D.

(3.) A contraction of the pupil, which began from the 5th to the 15th minute, reached its maximum from the 15th to the 25th minute, and disappeared from the 24th to the 48th hours.

(4.) An increase in the range of accommodation, which began from the 5th to the 10th minute, and was in three cases preceded in the first 7 to 10 minutes, and in two others was interrupted from the 10th to the 45th minute by a decrease. In the remaining case no decrease occurred. The decrease at its maximum varied from 0·73 D. to 3·76 D. The maximum increase occurred from the 42nd to the 80th minute, and varied from 3·76 D. to 9·94 D. The increase disappeared in from 8 to 9 hours.

Taking the average of these results, it seems that eserine caused—

(1.) An approximation of the far point, which began at the 7·33 minute, reached its maximum in 15·67 minutes, and disappeared in 48·67 minutes. The maximum approximation was equivalent to 5·85 D.

(2.) An approximation of the near point, which began in 4·33 minutes, reached its maximum in 26·17 minutes, and disappeared in less than 8 to 9 hours. The maximum approximation was equivalent to 9·15 D.

(3.) A contraction of the pupil, which began in 9·83 minutes, reached its maximum in 20·83 minutes, and disappeared in 24 to 48 hours.

(4.) An increase in the range of accommodation, which began in 6·5 minutes, reached its maximum in 52·67 minutes, and disappeared in 8 to 9 hours. The maximum increase was equivalent to 6·89 D., whilst the average normal range was 8·95 D.; that is, the proportion of the increase to the normal range was 0·77 D. This increase was in three cases preceded in the first 8 minutes, and in two other cases was interrupted between the 10th and 35th minutes by a decrease, which at its maximum was equivalent to 2·26 D.; that is, 0·25 of the normal range.

We have also made a number of controlling observations which, in their general result, confirm the preceding cases.

Generalisation.

We are now in a position to generalise on the action of eserine on non-presbyopic emmetropic and ametropic eyes, but before doing so we desire to refer to the work already published on this subject.

Donders (1) gives a detailed description (with a chart) of the action of extract of Calabar bean on the eye of Mr. Hamer, who had a far point of 48 and a near point of about 5 inches. The drug produced an approximation of the far and near points which reached its maximum in 30 to 40 minutes. The maximum contraction of the pupil occurred about the same time. The far point returned to its normal position in 110 to 120 minutes, but the near point remained approximated and the pupil continued contracted for a much longer time. Thus there was an increase in the range of accommodation preceded by a decrease which seems to have reached its maximum (less than 1·5 D.) in 10 to 20 minutes, whilst the increase attained its maximum (not more than 2 D.) between the 80th and 90th minutes, that is, when the far point was just returning to normal. Donders states that in another case he observed this increase of range without any antecedent diminution. Finally, he says that he has noticed an increased amount of astigmatism whilst determining the position of the near point after the use of eserine.

Von Reuss (27 and 27A) whilst ascertaining the influence of eserine on the radius of the cornea, made numerous measurements of the position of the far point. He found that the maximum effect with a 1 per cent. solution always occurred from the 20th to the 40th minute, and also that "der grösste Brechwerth des eingetretenen scheinbaren Refractions zuwachses betrug $\frac{1}{60}$, $\frac{1}{50}$, $\frac{1}{20}$, $\frac{1}{10}$,

$\frac{1}{9}, \frac{1}{7}, \frac{1}{5\frac{1}{2}}, \frac{1}{4\frac{1}{2}}, \frac{1}{4}, \frac{1}{3\frac{1}{2}}, \frac{1}{3}$, je einmal, $\frac{1}{2\frac{1}{2}}$ zweimal." He does not, however, refer to any alteration in the range of accommodation.

Königstein (26) made some observations on the local action of a 1 per cent. solution of eserine. He found that the influence on the far point had almost passed away in an hour, whilst the approximation of the near point only ceased with the myosis. Therefore indirectly he noticed the increase in the range of accommodation.

Reich (30) found in the case of a man aged 37, who was suffering from paralysis of the accommodation, and whose range was reduced to 3 D., that eserine produced an increase of 4 D. in 30 minutes. He did not, however, investigate its influence on healthy eyes.

Zehender (37) applied a ½ per cent. "Salicylsäuren Physostigmin (eserine)" to the eyes of two of his assistants. He made three sets of observations. In the first he determined the near point by Burchardt's test-dots; in the second he estimated the far point by Burchardt's tests and by glasses, and draws attention to the influence of the narrowed pupil on the visual acuity. He made the third set of measurements of the near point with a Graefe's "stabchen optometer." Zehender prefaces his tables with the following statement: "Die Einwirkung dieses Mittels auf die Accommodation muss dagegen in Abrede genommen, oder mindestens, in Hinblick auf einige die Reinheit, des Versuches störende Momente als zweifelhaft und wiederholter Prüfung bedürftig hingestellt werden." The action of the drug seems to have been very irregular, especially in the eye of his pupil A. (Angelucci), whose far point was sometimes approximated, and sometimes removed to a further point than usual under its influence. No very clear statement as to the alteration of the range occurs in this paper, nor does Zehender's attention seem to have been especially directed to this point.

Krenchel (18) in contrasting the action of physostigmin and muscarin, says that physostigmin begins by approximating the near point and so increasing the range of accommodation, but stronger action causes the far point to approach.

As far, then, as we can ascertain, no one, since the time of the first and accurate investigation of Donders, has made this a point of special study, and even Donders does not state whether he made observations on different kinds of eyes.

It will be seen from our tables that the near point is obviously affected before the far point. This is confirmatory of Krenchel's observations, but differs from the observation of Donders on the eye of Mr. Hamer. But we find that the maximum approximation of the far point occurred before that of the near point, in this agreeing with Donders' table. The action on the pupil was obviously later than the action on the accommodation, but the maximum contraction of the pupil occurred nearly midway between the times of maximum affection of the far and near points, so that it seems that the time of the maximum affection of the accommodation and pupil were identical. The action on the far point usually ceased within an hour; in this we agree with Königstein, but we differ from him with regard to the time when the influence on the near point ceased. He states that the approximation of the near point only ceased with the disappearance of the myosis, whereas our table shows that the myosis remained for several hours after the effect of the drug on the near point had passed off. On comparing our results relative to the alteration of the range with those of Donders (the only other direct observation on the point we can find), it seems that the increase of the range which occurred in the case of Mr. Hamer bears a very much smaller proportion to its normal range than that which we found to be the average: in fact in none of our cases was the maximum increase as low as that which Donders found in Mr. Hamer's eye. This discrepancy may be accounted for by the fact that Donders used extract of calabar, and only refers directly to the action of the drug on one eye. With reference to the former point A. Weber (17) writes that "Extract. Calabarense ungefähr 10—15 mal schwächer wirkt als das Eserin."

The action of eserine during the first hour is violent, being characterised by the well-known clonic spasms of the accommodation and by great irregularity in its action, so that the charts only represent the mean result. It is in consequence of this irregularity of action that we feel ourselves unable to endorse the conclusions of Donders relative to the effect of eserine in producing astigmatism, for we know of no apparatus by which both meridians can be measured at the same time, and during the first hour of the action of eserine one cannot be sure that the far or near point will occupy the same position during any two consecutive moments, hence it is quite impossible to accurately compare the measurements taken in one meridian with those taken in another.

Explanation of the Changes in the Range of Accommodation produced by Eserine.

Does eserine cause the change of position of the far point by—

(A.) Altering the shape of the globe; that is, by altering the curve of the cornea?
(B.) By altering the position of the lens?
(C.) By its action on the iris? Or
(D.) By producing cramp of the ciliary muscle?

(A.) The first question to be answered is, What effect does eserine produce on the intraocular tension, and what effect could any tension alteration have on the corneal curve?

Lacqueur (19) and also Lucius (20) found that eserine reduced the tension in glaucoma, but the former says, "Am nicht glaucomatösen Menschenauge sowie am normalen Kaninchenauge habe ich nach wiederholten Physostigmineinträufelungen eine Veränderung des intraoculären Druckes nicht constatiren können." Hippel and Grunhagen (21) could not observe any pressure alteration after the application of eserine; whilst Adamück (5) found that it increased the tension. The observations of A. Weber (17), made with the tonometer on the living eye in man, show that eserine, whilst it diminished the tension in the anterior chamber, raised it in the vitreous.

Pfluger found that eserine first increased and then diminished the tension. Finally Graser (39), after making careful manometric observations on the eyes of living animals, and after reviewing the literature of the subject, concludes that "Eserin, in gleicher (in der gewöhnlich zur Herbeiführung von Myosis gebrauchten Dosis in den Bindehautsack gebracht) Weise angewendet, bedingt zunächst eine Drucksteigerung, der aber in allen Fällen nach Verlauf von spätestens einer Stunde (nachdem sich Myosis entwickelt) eine Druckerniedrigung unter die Norm nachfolgt." The decrease seems in ten cats' eyes to have varied from 4 to 12 mm. Hg. It seems to us that this result renders the earlier want of agreement explicable.

Could this increase cause an alteration of the corneal curve sufficient to account for even a part of the far point approximation? Schelske (2) injected fluid into the enucleated eyes of rabbits and of men, and so raised the intraocular tension. At a certain pressure he found that the cornea became flatter. Donders (3), quoted by Hoffmann, says: "Ein paar Mal haben wir auch den Radius der Hornhaut mit Hülfe des Ophthalmometers an einem glaukomatösen und nicht-glaucomatösen Auge desselben Individuums bestimmt, oder auch den desselben glaukomatösen Auges vor und nach der Operation verglichen, ohne einen bestimmten Einfluss des intraoculären Drucks auf die Wölbung der Cornea erkennen zu konnen." Coccius (4), as quoted by V. Reuss, says: "Selbst in solchen Fällen einseitiger Erkrankung, 'wo hohe Spannung, weit vorgerückte Amblyopie, Gesichtsfeldbeschränkung, Druck-Excavation des Sehnerven, Vorhandensein des Arterienpulses,' zu constatiren waren, konnte doch im Vergleich mit dem gesunden Auge keine Krümmungsabweichung gefunden werden; er sucht den Grund hierfür in der Rigidität der Sclerotica. Dagegen konnte er eine Abflachung der Cornea an einem Auge beobachten, an welchem nach Discission einer Cataracta Spannungserhöhung aufgetreten war, und wo sich der Radius der Cornea von 7·75 mm. an 8·20 mm. vergrössert hatte." Mauthner (41) (quoted by Reuss), also found no alteration of the corneal curve in glaucoma, but in an eye with swollen traumatic cataract the corneal radius before the removal of the lens was 8·5 mm., and after its removal it became 7·73 mm. It would therefore seem that if the excessive tension above described could not produce an alteration of the curvature. that the much slighter effect of eserine would also be powerless, but we must now draw attention to a long and elaborate paper by Von Reuss (27A).

With the ophthalmometer of Helmholtz he measured the corneal curve at periodical intervals after the application of eserine. He found generally, but not invariably, that in rough correspondence with the approximation of the far point there was an alteration of the corneal curve (usually diminution of the radius), which disappeared in an hour. He allowed for working errors 0·04 mm. (but Mauthner gives a larger margin), and says: "Es muss vor Allem festgestellt werden, dass die gefundenen Veränderungen nicht innerhalb der Grenzen derselben zu liegen kommen." A careful survey of his tables and charts shows, however, that his results were exceedingly variable, and that there was not an accurate correspondence either in point of time or of quantity between the corneal changes and those of the far point. In fact he himself admits that "die Einwirkung auf die Accommodation findet beinahe immer früher statt, als die auf die

Hornhautwölbung, und das Maximum der Accommodations-Anspannung tritt fast ausnahmslos früher ein, als die grösste Längen-Abnahme des Radius." However, he adds: "Doch liegt die Rückkehr zur Norm bezüglich beider Veränderungen nicht zu weit auseinander, meist ist es beim Radius früher der Fall, selten später oder gleichzeitig." As to the cause of this corneal alteration, he writes further: "Wenn die longitudinalen Fasern (ciliary muscles) sich ad Maximum verkürzen, so werden sie vor Allem die Choroidea nach vorne ziehen und den Glaskörper unter einen erhöhten Druck setzen; es wird dann ein Moment kommen, wo ein weiteres Nachvorneziehen nicht mehr möglich ist, wo leichter eine weitere Retraction der Irisperipherie eintritt, und es wird die Zugrichtung nach hinten aussen zur Geltung kommen." "Die grösste Abnahme betrug einmal 0·04 mm., nach wiederholtem Einträufeln 0·08 mm., einmal 0·07 mm., zweimal 0·09 mm., dreimal 0·10 mm., einmal 0·14 mm., 0·088 mm., 0·099 mm., 0·32 mm." This last result was only found once, and is therefore to be received with reserve. Now it seems to us that this assumption relative to the cause of the alteration of the corneal curve is unwarranted, for the far point is not usually approximated by eserine to the place which the near point occupied before the application, that is to say, that the tension of the ciliary muscle produced by normal accommodation to the near point is usually greater than the tension produced by the application of eserine, and he himself states that the corneal radius does not alter during normal accommodation. Considering the irregularity of his results, the absence of definite information as to the influence of altered intraocular tension on the curve of the cornea, and the want of detailed correspondence between the far point alteration and the change in the corneal curve, it seems that there is room for further investigation on this point.

We have endeavoured to measure the corneal curve before and after the application of eserine by a less elaborate but very convenient method, viz., that recommended by Hirschberg (16, 42): "um die Messung des Hornhautkrümmungsradius zu einer bequemen und schnell ausführbaren Methode der Praxis zu machen, werden in Höhe des zu untersuchenden Auges zwei Lichtflammen aufgestellt, so dass ihre gegenseitige Entfernung 1 m. beträgt und das zu untersuchende Auge vom Mittelpunkt ihrer Halbirungslinie 1 m. entfernt ist. Mit einer Lupe (oder mit dem Pupillometer von Coccius) misst man β, die Grösse der Distanz der beiden Lichtflammen im Spiegelbildchen der Hornhaut, dann ist direct β die Brennweite oder der halbe Krümmungsradius des Hornhautspiegels. Die Untersuchung ist so schnell ausführbar, dass sie ebenso gut wie die Ophthalmoskopie auf jeden Patienten angewendet werden kann, und genau genug, um Abweichungen der Hornhautkrümmung von dem Mittel erkennen zu lassen."

To the eye of a man aged 24, in whom an iridectomy had been performed after an injury, but whose eye had perfectly recovered, we applied eserine solution, having first measured the radius of the cornea. Some time previously we had applied atropine to the eye and had estimated the refraction by retinoscopy: before atropine the vision of the injured eye $= \frac{6}{9}$: by retinoscopy in the meridian of the coloboma (down and out) a — 0·25 lens reversed the shadow, whilst in the opposite meridian a +1 D. over corrected.

Under atropine with $\frac{\text{cyl. } -1{\cdot}25 \text{ D. } 30^\circ \text{ out}}{\text{sph. } -0{\cdot}5 \text{ D.}}$ the vision $= \frac{6}{6}$. The far point before the application of eserine, that is when the eye was not under the influence of any drug, was for lines in the axis of the coloboma 250 cm., and for those in the opposite axis 125 cm.: the near points being respectively 10·5 and 10 cm. A careful measurement of the cornea made at this time with all the points distant 2 metres (instead of 1 to ensure greater absolute accuracy) gave a radius of 7·5 mm. When, after the application of eserine, the far points had both reached 32 cm. and the near points 6·5 cm., on making observations under exactly the same circumstances, we were unable to observe the slightest change in the indicated radius, although whilst accommodating for the near point the tension of the ciliary muscle was greater than under normal circumstances. Now, taking 8 mm. as the normal radius of the cornea and 1·337 as its refractive index and 1 as the index of air, we have $\frac{1\cdot337 - 1}{1\cdot337} \times \frac{1}{8} = \frac{1}{f}$, where f = the principal focus: from which $\frac{0\cdot337}{8} = \frac{1\cdot337}{f} + \frac{1}{\infty}$ mm.: $f = 31\cdot7$ mm., giving $R = \frac{0\cdot337}{0\cdot0421} + \frac{1}{\infty}$ where ∞ = the *punctum remotum.* In our case ∞ was 2000 mm. (mean) before the application of eserine, and 320 mm. after. If the cornea alone produced this change there should be a difference between the measurements taken when the far-point was in these two positions of $\frac{0\cdot47}{2}$ mm. Since, however, it would have been quite possible for us to have overlooked a change of less than 0·25 mm., we modified the experiment as follows:—We measured the radius of curvature of the L. cornea of C. P. (on whose eyes the action of pilocarpine and eserine is noted in this paper) by fixing the lights as before at 1 metre; this time, however, whilst the observed eye was fixed on a distant object we placed our own eyes whilst making the observation at a definite distance from the observed cornea. We then held a mm. measure as close to the cornea as possible and read off the distance between the centre of the two images. With care we could read to 0·25 mm. It will be remembered that C. P.'s far point was 1000 mm. and his near point 90 mm. We found the radius of his cornea to be 7·5 mm. (this of course not being an absolute value). After a profuse application of eserine the far point was brought to 200 mm. and the near point to 45 mm. We now made several careful examinations of the cornea in the same manner as before, and also whilst the patient was accommodating to his utmost. We could not, however, find any trace of alteration in the radius. Now if the alteration of the corneal curve had been instrumental in causing the approximation of the far point even (by an application of the preceding formula) there should have been a difference of about 1·04 mm. radius, that is, a difference of 0·5 mm. in our measurements.

However, to conclusively settle the matter we adopted an entirely different plan. We placed over the eye an accurately fitting metal cup with a plane glass front. The cup was filled with warm normal saline solution (0·65 per cent.) and the observed, looking through this bath, practically possessed a plane cornea and was, consequently, highly hypermetropic. It will be seen that this apparatus is only a variety of that used by Coccius in proving that the cornea plays no part in normal accommodation. With this apparatus it was absolutely impossible that changes in the cornea could influence the position of the far or near points.

We applied this apparatus, filled with saline solution, to the left eye of C. P., and the vision was reduced to a dim perception of large objects: on placing a +27 D. lens in front of the glass cornea the vision again $= \frac{6}{6}$. With a +28 D. lens (to bring the far point within a measurable distance) the far point was at 125 cm. and the near point at 14 cm., the vertical meridian only being measured. The apparatus was then removed and eserine profusely applied; after the lapse of eight minutes the apparatus was readjusted exactly as before.

Table of Observations.

Time.	Near point.	Far point.
Before application ..	14 cm.	125 cm.
After application—		
10 minutes	7	40
15 ,, ...	8·5	39
20 ,, ...	7	37
35 ,, ...	8	42
50 ,, ...	9·5	125
55 ,, ...	8	91
60 ,, ...	9	80
65 ,, ...	8	99
70 ,, ...	9·5	105
80 ,, ...	8·5	125

On removing the apparatus the distant vision $= \frac{6}{6}$ and the near point was at 4·5 cm. distance. The irregularity of the observations between the 20th and the 50th minutes was due to sickness which temporarily affected the patient. (*See* also Chart of Case 16.) This table and chart should be compared with Table II.

In this eye eserine caused, when the measurements were taken with the apparatus—

(1.) An approximation of the far point, which began in less than 10 minutes, reached its maximum at the 20th minute, and returned to its normal position practically at the 80th minute. The maximum approximation was equi valent to 1·9 D.

(2.) An approximation of the near point, which began within 10 minutes, reached its maximum at the 10th minute, and remained to a material extent when the observations were discontinued at the 80th minute. The maximum approximation was equivalent to 7·14 D.

(3.) An increase in the range of accommodation, which reached its maximum at the 10th minute, and remained to a material degree at the 80th minute, when the observations were discontinued. The maximum approximation was equivalent to 5·44 D., that is 0·86 of the normal range

6·34 D. (with the apparatus), so that the total range at this time was 11·78 D.

Table showing the Action of Eserine on the Left Eye of C. P.

With the apparatus.		Without the apparatus.	
Time.	Range of accommodation.	Time.	Range of accommodation.
Before application	6·34 D.	*Before application*	12·11 D.
After application 10th minute ...	11·78 D.	*After application* 12th minute	17·76 D.
35th ” ...	10·12 D.	36th ”	18·81 D.
50th ” ...	9·73 D.	54th ”	22·05 D. Far point in original position.
80th ” ...	10·96 D. Far point in original position.	72nd ”	21 D.

From this table it will be seen that before application the range of accommodation with the apparatus was to that without the apparatus as 1 : 1·91. At the only time at which comparisons are again possible, that is, when the far points had returned to the normal position (80th with the apparatus, 54th without), the ratio was 1 : 2·01. It therefore seems that the influence of eserine on the accommodation is relatively the same when a plane cornea is substituted for a curved one.

We made, however, a controlling experiment, XVI*a*.

G. L., aged 20, emmetrope V. $= \frac{6}{6}$, near point at 11 cm. When the same apparatus, filled with normal saline solution, was applied to the left eye the vision was reduced to a mere perception of light, and with the aid of a + 23 D. lens, carefully centred, it became $\frac{6}{6}$. With a + 24 D. the far point was 100 cm. and the near point 16 cm. With a + 25 D. the far point was 47 cm. and the near point 14·5 D. These distances were measured as before from the auxiliary lens. The apparatus was removed, eserine profusely applied, and after a lapse of 6 or 7 minutes it was readjusted. The following table shows the changes in the position of the far and near points produced by the action of eserine :—

Time.	Near point.	Far point.
Before application without apparatus	11 cm.	∞
Before application with apparatus ...	14·5	47 cm.
15 minutes after application with apparatus	15	25
20 minutes after with apparatus	11	20
25 minutes after with apparatus	11	15
25 minutes after without apparatus ..	9	16

At the 25th minute the observations were discontinued on account of the patient being sick and faint. Nevertheless the table shows—

(1.) The range of accommodation before application was 9·09 D. without the apparatus, and 4·77 D. with it. The ratio of the one to the other being 1 : 0·52.

(2.) At the 25th minute the range of accommodation was 4·86 D. without the apparatus, and 2·42 D. with it: the ratio of the one to the other being 1 : 0·49.

Since then we have been unable to observe any alteration in the corneal radius following the application of eserine, and since we have been unable to notice any material difference in the extent to which the near and far points were altered in position by the eserine when a plane was substituted for a curved cornea (that is relatively, for the alteration of the position of the nodal point necessarily alters the extent of range), we therefore conclude "that this alteration of the corneal radius, which Von Reuss has described with such minuteness and care, is neither a constant nor necessary accompaniment to the change in the range of accommodation; and that the influence the cornea exerts in the approximation of the far or the near point, if it constantly exists, is very trivial." Indeed, we further think it probable that the alterations he describes have some other source than the contraction of the ciliary muscle.

(B.) Can the change in the range of accommodation be due to an alteration in the position of the lens?

To this question we find ourselves unable to give a definite reply; for although we believe that we may state positively that no movement of translation of the lens takes place normally in accommodation; and although we feel that we are justified in asserting that the whole of the increase produced by eserine is not due to any movement of the lens, yet we are unable to make a positive statement that no movement of the lens occurs and that no part of the increase is due to any such movement: on the other hand we are unable to say such a movement takes place. Some slight forward movement of the lens is more than possible, since A. Weber (17) found that the contraction of the iris raises the tension in the vitreous whilst it diminishes that in the anterior chamber, thus confirming, we believe, Helmholtz's calculation. Since with an advance of the lens the nodal point of the dioptric system is also advanced, it is evident that any alteration in the curve of the lens will now produce a greater effect than formerly.

That increased posterior tension will produce a forward movement of the lens is sufficiently proved by the pathology of glaucoma; on the other hand the increased tension in the vitreous resulting from the application of eserine is hardly even for argument's sake to be compared with that in glaucoma. Therefore we are compelled to close this discussion with the following statement:—

"A forward movement of the lens may be produced by eserine and this may contribute slightly to the alteration in the position of the far and near points."

(C.) Can the great contraction of the sphincter pupillæ which eserine causes have any influence in producing the changes in the position of the far and near points?

It is very difficult to understand in what manner this could exert any influence. In Hjort's case there was no iris and the changes in the position of the far and near points were well marked; in our own case of iridectomy the functional destruction of the iris did not influence the result, and further, since the far point approximates and recedes without any reference to the iris-contraction, and the near point returns to normal before the pupil has returned to its normal size, it seems to us that there is not the least evidence to support such a view, and we therefore feel able to make this positive statement: "the contraction of the iris has no appreciable influence on the accommodative changes produced by eserine."

(D.) It might seem sufficient to state that having proved that the other factors do not produce the change in the range of accommodation, the ciliary muscle is the only structure which can effect them. But it is now our intention to endeavour to show that there is direct evidence of the action of eserine on the accommodative apparatus. We think that we are justified in taking it as proved "that accommodation for the near is effected by the contraction of the ciliary muscle, which draws forward the ciliary processes, relaxes the suspensory ligament, and allows the anterior surface of the lens to become more convex." What evidence is there, then, that the application of eserine can produce this change?

Professor O. Becker (6), quoted by Hjort, found—

"(1.) Dass die Ciliarfortsätze ein mit der Weite der Pupille wechselndes Volumen zeigen, indem sie gegen die

Sehaxe vorrücken wenn die Pupille sich beim Sehen in die Ferne oder auf Atropin erweitert, sich aber gegen den Ciliarkörper zurückziehen wenn die Pupille sich bei Accommodations-Anspannung oder auf Calabarextract verengert.

"(2.) Dass die Ciliarfortsätze niemals die Linse berühren.

"(3.) Dass bei Accommodation für die Nähe und bei Einlegen von Calabarpapier der schwarze Linsenrand breiter, bei Entspannung des Auges und Einträufeln von Atropinlösung schmäler wurde, was sich nur durch eine Abstumpfung und Zuschärfung des Linsenrandes erklären lässt."

Hjort (14), however, had a splendid opportunity of observing the changes in the position of parts in a patient whose iris had completely disappeared in consequence of a dynamite explosion, the eye being otherwise uninjured. The range of accommodation was in no wise affected by the injury, but it was a little more myopic than its fellow. Hjort, after making some careful observations, writes as follows: "Bei Calabareinwirkung zeigte sich eben dasselbe (as by accommodation for 6 or 8 inches), nur in sehr viel auffallenderer Weise. Die Ciliarfortsätze traten während der Nähe-Accommodation so stark hervor, dass man an einzelnen Stellen den Boden der zwischenliegenden Furchen sehen konnte, der Linsenrand wurde deutlich breiter, während der Abstand derselben von den Spitzen der Ciliarfortsätze ungeändert erschien . . . Während der stärksten Calabareinwirkung (nach 30 Minuten) zeigte sich der Fernpunkt von 28 bis 6 Zoll hereingerückt. He found that during normal accommodation for 6 or 8 inches—

"(1.) Der schwarze Linsenrand wurde sichtbar breiter.

"(2.) Die Ciliarfortsätze rückten hervor, der Augenachse näher, und schienen gleichzeitig zu schwellen.

"(3.) In dem Abstand zwischen Linsenrand und Spitze der Ciliarfortsätze (Zonularraum) konnte keine Aenderung beobachtet werden."

In two albinos in whom eserine, locally applied, produced the most profound myosis, Hjort confirmed this alteration of the position of the ciliary processes during accommodation and during the action of eserine. He says that Becker's failure to see this change was accounted for by his not using calabar, which exaggerates the normal changes. We desire to lay particular stress on the fact that Hjort could not distinguish between the action of calabar and normal accommodation, except that with calabar the changes were more marked, that is, the difference was one of quantity only.

Bauerlein (15) made similar observations on eight albinos and on many iridectomied eyes, and confirmed Hjort's statements, whilst A. Weber (17) goes almost further. Thus, he says: "Mit vollständiger Evidenz ist am iridectomirten Auge nach Anwendung von Calabar zu sehen, dass die Ciliarfortsätze nicht nur weit hervorrücken, sondern auch so mächtig anschwellen dass sie sich in dem Zwischenraum des Coloboms nach aussen umschlagen und so über das Niveau der Irisfläche hervorwölben . . . Dass aber die Turgescenz nicht die einzige Ursache des Sichtbarwerdens resp. des deutlicheren Hervortretens der Ciliarprocesse ist, sondern dass wirklich ein Vorrücken derselben statt hat, davon hatten wir, abgesehen von der aprioristischen Annahme, einmal einen unzweideutigen Beweis: an diesem Auge sah man die aus den Interstitien zwischen je zwei Processus fächerartig sich ausbreitenden Büschel ganz leicht getrübter Zonulafasern, die vor der Calabar-Anwendung alle deutlich vom Linsenrande her nach hinten zogen, nach eingetretener Calabarwirkung im seitlichen Theil des Coloboms horizontal im mittleren Theile, wo die Ciliarfortsätze nach aussen umgeschlagen waren, von der Linse gegen die Peripherie sogar etwas nach vorne verlaufen."

The evidence of these three observers, Hjort, Bauerlein, and A. Weber, seems to us conclusive that the action of eserine is to produce the identical changes which occur in accommodation for a near object.

Coupling this with our own results, obtained whilst measuring the corneal curve in order to eliminate the supposed influence of the cornea on the position of the far point, we are enabled to conclude that—The change in position of the far and near points which eserine produces, and the consequent alteration in the range of accommodation, must be referred chiefly, if not entirely, to changes produced by the eserine in the ciliary muscle itself, since it has been shown that neither the changes in the iris nor the cornea, nor an alteration in the position of the lens, could produce more than a fractional part of the change, and also since the influence of the first two factors can be, at all events sometimes, entirely eliminated.

Having then localised the action of eserine to the accommodation apparatus, it remains for us to consider what is the nature of that action. In the later stage, when the far point has receded and the near point remains materially approximated, and the range of accommodation is thus increased, it is evident that eserine has acted like strychnia (Donders), and we have to deal with some change in the muscle which causes it to respond more powerfully than usual to volitional impulses. The probable meaning of the first approximation of the far point is that eserine at first causes a spasm (accommodationskrampf) with increased response to volitional impulses, and that the first effect passes off the more rapidly of the two.

The Action of Eserine on Presbyopes.

So far as we can ascertain, no reference to this point is to be found in any preceding paper.

CASE VII.—C. B., æt. 50. *Right Eye.* V. = $\frac{6}{18}$. Hm. 2 D. = $\frac{6}{6}$.
Moderate Application. Position of the Near Point Estimated in Vertical Meridian only. Position of Far Point Estimated by means of Glasses and Snellen's Types.

Time.	Pupil.	Near point.	Far point.
Before application......	3·5 mm.	42 cm.	– 50 cm.
After application—			
5 minutes	3·5	36	0
10 ,, ...	2	26	200
15 ,, ...	2	15	200
20 ,, ...	2	9·5	200
25 ,, ...	2	7	40
35 ,, ...	2	7·5	40
40 ,, ...	2	7	66
50 ,, ...	2	7	66
55 ,, ...	2	7·5	66
60 ,, ...	2	7·5	0
65 ,, ...	2	7·5	0
70 ,, ...	2	7·5	0
80 ,, ...	2	7·5	0
90 ,, ...	2	7·5	0
95 ,, ...	2	10	–133

After the pupil became contracted, whether in consequence or not we cannot say, the distant vision was not very good even with correcting glasses $\left(V. = \frac{6}{9} \text{ instead of } \frac{6}{6}\right)$. Towards the end of the observation, however, the sharpness of vision returned though the pupil was still contracted.

In this eye eserine caused—

(1.) An approximation of the far point, which began at the 5th, reached its maximum at the 25th, and had nearly passed away at the 95th minute. The maximum approximation was equivalent to 4·5 D.

(2.) An approximation of the near point, which began at the 5th minute, reached its maximum at the 25th minute, and remained greatly approximated at the 95th minute, when the observations were discontinued. The maximum approximation was equivalent to 11·91 D.

(3.) A contraction of the pupil, which began and reached its maximum between the 5th and 10th minute, and remained to the same degree at the 95th minute, when the observations were discontinued.

(4.) An increase in the range of accommodation, preceded in the first 10 minutes by a decrease which at its maximum amounted to 1·6 D.; that is, nearly a third of the normal range (4·38 D.). The increase reached its maximum at the 60th minute, and at that time amounted to 8·95 D., that is, to double the normal range, so that the range was then 13·33 D. The increase was still great at the 95th minute. (*See* Chart.)

CASE VIII.—*Left Eye* of Same Patient. Moderate Application.
V. same as in Right.

Time.	Pupil.	Near point.	Far point.
Before application..	3·5 mm.	42 cm.	− 50 cm.
After application—			
5 minutes	3·5	32	−133
10 ,, ...	2	22	−200
15 ,, ...	2	11	−400
20 ,, ...	2	7	66
25 ,, ...	2	6·5	66
35 ,, ...	2	6	66
40 ,, ...	2	6	100
50 ,, ...	2	6	66
55 ,, ...	2	6·5	200
60 ,, ...	2	7	−400
65 ,, ...	2	..	−400
70 ,, ...	2	7	−200
80 ,, ...	2	7	−200
90 ,, ...	2	..	−200
95 ,, ...	2	9	−100

At this time with both eyes the Hm. = 1·5 D. In this eye the distant vision remained (with glasses) good throughout $\left(\frac{6}{6}\right)$.

In this eye eserine caused—

(1.) An approximation of the far point, which began at the 5th, reached its maximum at the 20th, and had nearly passed away at the 95th minute. The maximum approximation was equivalent to 3·52 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum at the 35th, and remained to a great extent at the 95th minute, when the observations were discontinued. The maximum approximation was equivalent to 14·29 D.

(3.) A contraction of the pupil, which began and reached its maximum between the 5th and 10th minutes, and remained to the same degree at the 95th minute.

(4.) An increase in the range of accommodation, preceded in the first 5 minutes by a decrease which at its maximum was 0·51 D. The increase reached its maximum at the 40th minute, and at that time was 11·29 D., that is, about 2·5 times the normal range (4·38 D.), so that the range was then 15·67 D. The increase was still considerable at the 95th minute.

CASE IX.—E. P., æt. 60. *Left Eye.* Profuse Application.

$$V. = \frac{6}{60}. \quad Hm.\ 2\ D. = \frac{6}{6}.$$

Time.	Pupil.	Near point.	Far point.
Before application..	3·5 mm.	56 cm.	− 50 cm.
After application—			
5 minutes	3	35	An endeavour was made to estimate the far point with the optometer, but the results were wholly unsatisfactory, irregular, and unreliable.
10 ,, ...	2	37	
15 ,, ...	1·5	25	
20 ,, ...	1 5	30	
25 ,, ...	1·5	28	
30 ,, ...	1·5	34	
35 ,, ...	1·5	40	
45 ,, ...	1·5	40	

It will be seen that in this case eserine caused a very trivial approximation of the near point, that is, only 1·5 D.

even at its maximum, and that this effect rapidly passed away. What the effect on the far point was we cannot definitely state, and therefore the alteration in the range also cannot be given, but it is nearly certain that it was decreased, and but slightly if at all subsequently increased.

In this case eserine caused—

(1.) An approximation of the near point, which began at the 5th minute, reached its maximum at the 15th, and still existed to some extent at the 45th minute. The maximum was equivalent to 2·21 D.

(2.) A contraction of the pupil, which began at the 5th and reached its maximum at the 15th minute, and remained in this condition at the 45th minute, when the observations were discontinued.

Case X.—M. C., æt. 53. *Left Eye.* V. = $\frac{6}{60}$. Hm. 2 D. = $\frac{6}{6}$.

Profuse Application.

Time.	Pupil.	Near point.	Far point.
Before application..	3·5 mm.	60 cm.	− 50 cm.
After application—			
5 minutes	3	36	150
10 ,, ...	2·5	18	50
15 ,, ...	2	8	45
20 ,, ...	2	6	42
25 ,, ...	2	5	55
30 ,, ...	2	5	65
35 ,, ...	2	5	Nearly normal, that is, beyond reach of measurement with the optometer.
40 ,, ...	2	5·5	
45 ,, ...	2	5·5	

In this case eserine caused—

(1.) An approximation of the far point, which began at the 5th, reached its maximum at the 20th, and disappeared probably between the 40th and 50th minutes. The maximum approximation was equivalent to 4·38 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum at the 25th, and remained to a considerable degree at the 45th minute, when the observations were discontinued. The maximum approximation was equivalent to 18·33 D.

(3.) A contraction of the pupil, which began at the 5th, reached its maximum at the 15th, and remained to the same degree at the 45th minute.

(4.) An increase in the range of accommodation, preceded in the first 10 minutes by a decrease which was 1·56 D. The increase reached its maximum at the 40th minute, and at that time was 16·52 D., that is, nearly five times the normal range (3·67 D.), so that the range was then 20·18 D. The increase was still considerable at the 45th minute.

Case XI.—E. D., æt. 49. *Left Eye.* V. = $\frac{6}{24}$. Hm. 1·5 D. = $\frac{6}{6}$.

Profuse Application.

Time.	Pupil.	Near point.	Far point.
Before application..	4·5 mm.	23 cm.	– 66·6 cm.
After application—			
5 minutes	4	18	– 66·6
10 "	2·5	14	125
15 "	2	11	125
20 "	2	11·5	86
25 "	2	11	66
30 "	2	11·5	90
35 "	2	12	100
40 "	2	12	–100
45 "	2	12·5	–100
50 "	2	13·5	– 66·6
60 "	2	14	
80 "	2	17	

The far point observations were taken partly by the optometer and partly by the test types and glasses.

In this eye eserine caused—

(1.) An approximation of the far point, which began at the 10th, reached its maximum at the 25th, and disappeared at the 60th minute. The maximum approximation was equivalent to 3·02 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum at the 15th, and remained to a considerable degree at the 80th minute, when the observations were discontinued. The maximum approximation was equivalent to 4·74 D.

(3.) A contraction of the pupil, which began at the 5th, reached its maximum at the 15th, and remained to the same degree at the 80th minute.

(4.) An increase of the range of accommodation, which reached its maximum at the 40th minute, and at that time was 3·48 D., that is, more than half the normal range (5·85 D.), so that the range was then 9·33 D. The increase was still considerable at the 80th minute.

Case XII.—E. F., æt. 51. *Right Eye.* V. = $\frac{6}{6}$. Hm. 0·5 D.

Profuse Application.

Time.	Pupil.	Near point.	Far point.
Before application . .	4·5 mm.	65 cm.	−200 cm.
After application—			
5 minutes	4	49	125
10 ,, ...	2·5	34	95
15 ,, ...	2	20	95
20 ,, ...	2	30	70
25 ,, ...	2	30	85
30 ,, ...	2	29	94
35 ,, ...	2	30	96
40 ,, ...	2	30	96
45 ,, ...	2	30	100
55 ,, ...	2	35	100
70 ,, ...	2	32	125
85 ,, ...	2	33	150
100 ,, ...	2	30	Apparently normal.
110 ,, ...	2	30	−200

In this case also the far point was estimated both with glasses and with the test types, but at the end of the observations, and in fact earlier also, it was at times very difficult to obtain vision of more than $\frac{6}{9}$ even with correcting glasses. In this eye eserine caused—

(1.) An approximation of the far point, which began at the 5th, reached its maximum at the 20th, and disappeared at the 100th minute. The maximum approximation was equivalent to 1·93 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum at the 15th, and remained to a considerable extent at the 110th minute, when the observations were discontinued. The maximum approximation was to 3·46 D.

(3.) A contraction of the pupil, which began at the 5th, reached its maximum at the 15th, and remained to the same degree at the 110th minute.

(4.) An increase in the range of accommodation, preceded in the first 10 minutes by a decrease which was 0·79 D., that is, nearly half the normal range (2·04 D). The increase reached its maximum at the 15th minute, and was at that time 1·91 D., that is, nearly equal to the normal range, so that the range was then 3·95 D. From the 20th to the 55th minutes the range was practically normal; from the 70th to the 110th an increase was again noticeable, which at its maximum (110th minute) was 1·79 D. (*See* Chart.)

Case XIII.—A. R., æt. 51. *Right Eye.* V. = $\frac{6}{6}$. Hm. 0·5 D.

Time.	Pupil.	Near point.	Far point.
Before application ..	5 mm.	65 cm.	−200 cm.
After application—			
5 minutes	4·5	52	125
10 „	3·5	35	70
15 „	3	22	40
20 „	2·5	10	30
25 „	2	9	34
30 „	2	9	22
35 „	2	9	35
40 „	2	11	30
45 „	2	9	30
50 „	2	9	30
55 „	2	10	34
60 „	2	9	30
65 „	2	9	35
70 „	2	8·5	30
75 „	2	9·5	50
80 „	2	10	52
85 „	2	9	50
90 „	2	8·5	54
95 „	2	10·5	55
100 „	2	9	55
105 „	2	9	60
110 „	2	9	60
120 „	2	8·5	60
130 „	2	9	70
145 „	2	9	77
155 „	2	..	75

The far point in this case was estimated partly by the optometer and partly by test glasses. In this case eserine caused—

(1.) An approximation of the far point, which began at the 5th, reached its maximum at the 30th, and had not altogether disappeared at the 155th minute. The maximum approximation was equivalent to 5·05 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum practically at the 25th (the actual lowest measurement was at the 70th, 90th, and 120th minutes, but the increased approximation was trivial), and remained to a great degree at the 145th minute, when the observations were discontinued. The maximum approximation was 10·22 D.

(3.) A contraction of the pupil, which began at the 5th, reached its maximum at the 25th, and remained to the same degree at the 155th minute.

(4.) An increase in the range of accommodation, preceded in the first 15 minutes by a decrease, which was 1·01 D., that is, nearly half the normal range 2·04 D. The increase reached its maximum at the 120th minute, and was at that time 8·05 D., that is, more than four times the normal range, so that the range then was 10·09 D. The increase was still great at the 155th minute.

Case XIV.—E. H., æt. 65. *Right Eye.* V. = $\frac{6}{60}$. Hm. 4·5 D. = $\frac{6}{6}$.

Profuse Application. Far Point Estimated by Test Types.

Time.	Pupil.	Near point.	Far point.
Before application..	5 mm.	70 cm.	Hm. 4·5
After application—			
5 minutes	3·5	60	
10 ,, ...	3	13	Hm. 1·5
15 ,, ...	2	10	
20 ,, ...	2	10	Hm. 2
25 ,, ...	2	10	
30 ,, ...	2	9	Hm. 2
35 ,, ...	2	9	
40 ,, ...	2	9	Hm. 1·5 D.
50 ,, ...	2	..	Hm. 1·5 D.
55 ,, ...	2	10	
60 ,, ...	2	12	Hm. 2·5
70 ,, ...	2	10	
85 ,, ...	2	9	Hm. 3 D.

In this case eserine caused—

(1.) An approximation of the far point, which reached its maximum at the 10th minute, and existed still to a slight extent at the 85th minute. The maximum increase was equivalent to 3 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum at the 30th, and was in that condition at the 85th minute. The maximum approximation was equivalent to 9·68 D.

(3.) A contraction of the pupil, which began at the 5th, reached its maximum at the 15th, and remained in that condition at the 85th minute, when the observations were discontinued.

(4.) An increase in the range of accommodation, which reached its maximum at the 85th minute. The increase at its maximum was equivalent to 8·18 D., that is, more than equal the normal range (5·93 D.), so that the range was then 14·11 D. (*See* Chart.)

CASE XV.—*Left Eye* of Same Patient. V. = $\frac{6}{60}$. Hm. 4·5 D. = $\frac{6}{6}$.

Application and Method as in R.

Time.	Pupil.	Near point.	Far point.
Before application..	5 mm.	70 cm.	Hm. 4·5 D.
After application—			
5 minutes	4	50	
10 „	3	7	Hm. 1·5 D.
15 „	2 (Oval horizontally)	5	
20 „	2	6	Hm. 1·5 D.
25 „	2	5·5	
30 „	2	6	Hm. 2·5 D.
35 „	2	9	
40 „	2	9	Hm. 2·5 D.
50 „	2	8	Hm. 3 D.
55 „	2	8	
60 „	2	6	Hm. 3·5 D.
70 „	2	8	Hm. 3 D.
85 „	2	7	Hm. 3·5 D.

In this eye eserine caused—

(1.) An approximation of the far point, which reached its maximum at the 10th, and had almost disappeared at the 85th minute, when the observations were discontinued. The maximum approximation was equivalent to 3 D.

(2.) An approximation of the near point, which began at the 5th, reached its maximum at the 15th, and existed still to a great extent at the 85th minute. The maximum approximation was equivalent to 18·57 D.

(3.) A contraction of the pupil, which began at the 5th, reached its maximum at the 15th, and remained in that condition at the 85th minute.

(4.) An increase in the range of accommodation, which reached its maximum at the 15th minute, and existed to nearly the same degree at the 85th minute. The maximum increase was 15·57 D., that is, more than 2·5 times the normal range (5·93 D.), so that the total range was then 21·5 D.

We have also applied eserine to the eye of a myope, aged 47, and we found that it caused an increase in the range of accommodation preceded by a slight diminution. Other controlling observations on presbyopic eyes have given results agreeing in the main, though differing in detail, with those recorded.

Summary.

We have given a detailed account of the action of eserine on the eyes of old people, in which the near point had receded respectively to 42, 42, 56, 60, 23, 65, 65, 70, 70 centimetres. All these eyes were hypermetropic, but two to the extent of 0·5 D. only, or practically emmetropic.

In these eyes eserine caused—

(1.) An approximation of the far point, which began from the 5th to the 10th minute, reached its maximum from the 10th to the 30th minute, and disappeared from the 40th to later than the 155th minute. The maximum approximation was equivalent to from 1·93 D. to 5·05 D.

(2.) An approximation of the near point, which began at the 5th minute, reached its maximum from the 15th to the 35th minute, and then was equivalent to from 2·21 D. to 18·57 D.

(3.) A contraction of the pupil, which began from the 5th to the 10th minute, reached its maximum from the 10th to the 25th minute, and was in this condition when the observations were discontinued, that is, from the 45th to the 155th minute.

(4.) An increase in the range of accommodation, preceded in 5 cases by a decrease during the first 5 to 15 minutes, which at its maximum was equivalent to from 0·51 D. to 1·6 D. The increase reached its maximum from the 15th to the 120th minutes, and then amounted to from 1·91 D. to 16·52 D., or from rather more than half to nearly five times the normal range.

Taking the average of these results, it is seen that eserine caused—

(1.) An approximation of the far point, which began in 5·83 minutes, reached its maximum in 20 minutes, and was then equivalent to 3·58 D.

(2.) An approximation of the near point, which began in 5 minutes, reached its maximum in 22·22 minutes, and was then equivalent to 10·38 D.

(3.) A contraction of the pupil, which began in 5·55 minutes, and reached its maximum in 15 minutes.

(4.) An increase in the range of accommodation, preceded in five cases by a decrease in the first 10 minutes, which amounted at its maximum to 1·09 D., that is, 0·33 of the average normal range of these five cases. The increase was 9·24 D., that is, 2·16 times the average normal range, which was 4·28 D. The maximum increase occurred at the 51·9 minute.

A reference to the following table shows—

(1.) That the commencement of the action and the time of maximum action on the far point were much the same in both presbyopic and non-presbyopic eyes. The amount of approximation, however, was greater in the case of the non-presbyopic eye.

(2.) That the commencement of the action and the time of maximum action on the near point were also much the same in both presbyopic and non-presbyopic eyes, but that the amount of approximation was a little greater in the presbyopic eyes.

(3.) The commencement of the action and the time of maximum action on the pupil seem to have occurred later in the non-presbyopic eyes.

(4.) The time of maximum increase of the range of accommodation was almost exactly the same in both cases. The absolute and relative amount of increase was greater in the presbyopic eye, although the total range at the time of maximum increase was greater in the non-presbyopic eye.

Basing, then, a conclusion on these average results, it seems that the chief difference between the action of eserine on the eyes of old and young people are—

(1.) That in presbyopic people the far point is not approximated so greatly, and (2) that the near point is approximated to about the same absolute, that is, to a greater relative extent.

The average result of the action of eserine on the 15 presbyopic and non-presbyopic eyes was—

(1.) An approximation of the far point, which began at the 6·58 minute, reached its maximum at the 18·14 minute, and passed away at the 55·22 minute. The maximum approximation was equivalent to 4·54 D.

(2.) An approximation of the near point, which began at the 4·73 minute, reached its maximum at the 23·8 minute, and was at its maximum equivalent to 9·89 D. The approximation of the near point disappeared in 8 to 9 hours.

(3.) A contraction of the pupil, which began at the 7·27 minute, reached its maximum at the 17·33 minute, and disappeared in from 24 to 48 hours.

(4.) An increase in the range of accommodation, preceded in eight cases—in the first 9·25 minutes, and interrupted in two others, 10—35 minutes—by a decrease of the range, which at its maximum was 1·68 D., or 0·26 of the normal range of these 10 cases. The increase of the range reached its maximum at the 52·22 minute, it was then 8·24 D., that is, 1·31 of the normal range (6·28 D.).

It is noteworthy that the maximum action on the pupil occurred before the maximum action on the accommodation.

It is evident that these presbyopic eyes may be divided into two groups, viz., those in which the range of accommodation was greatly increased (Nos. 8, 10, 13, 14, 15), and those in which the near point was not very much approximated, and consequently the range was not very much increased (Nos. 9, 11, 12).

The cause of this variability cannot lie in the age of the patients nor in the refractive character of the eyes, since eserine caused very great increase in the range of accommodation of older eyes with similar refraction. On dilating the pupils of a woman aged 55, whose V. $= \frac{6}{6}$ but whose range was only slightly increased by eserine, we found numerous cortical striæ in the periphery of the lens and also some haziness in the nucleus. It seemed to us that this would account for the peculiarity, but on applying the drug to the eye of another patient aged 55, with V. $= \frac{6}{12}$ Hm. 0·75 D., a marked increase in the range resulted; on dilating the pupil we found, however, rather more opacity than in the preceding case. We concluded that if the opacity is the index of the amount of rigidity the lens possesses, then the rigidity does not materially affect the action of eserine.

It seems to us that these observations on the eyes of old people throw some light on the causation of presbyopia; for if eserine by causing a contraction of the ciliary muscle can produce this increase in the range, it seems improbable that presbyopia can be dependent to any great extent on rigidity of the apparatus; for if the failure of the accommodation is due to lens rigidity it would appear to be quite impossible (in the present state of knowledge) that this contraction could cause an increase of lens convexity. That is to say, the muscle simply allows the lens to become more convex by relaxing the strain on the suspensory ligament, and if the lens were rigid no amount of relaxation of the suspensory ligament could bring about increased lens convexity. This view was supported to some extent by some experiments made by one of us at an earlier date. In the paper recording those experiments the following statement occurs :—" If presbyopia were in great measure due to rigidity of the apparatus and not to failure of the ciliary muscle, it would be expected that the relaxation periods of C. (who was æt. 35, emmetropic, near point 18 cm.) would be fairly long, but although the relaxation velocity, from 33 cm. to infinity, was fairly long, all others were too rapid for measurement ;" that is to say, no difference in the velocity of accommodation was observed in the case of a man aged 35 with a near point of 18 cm., and in the case of two people aged 19 and 22 respectively whose near points were 9 cm. and 11 cm., far points −100 cm. and −200 cm., and whose accommodation velocities, from the far to the near, were much more rapid than those of C. These facts appear to suggest that the failure of the ciliary muscle may account for some part of the presbyopic accommodative change, but it must be remembered that this statement depends on the assumption that Helmholtz's theory of the mechanism of accommodation is correct.

Table Showing the Results of the Application of Eserine to Presbyopic and Non-presbyopic Eyes (Averages).

	Far point.		Near point.		Pupil.		Increase of range.		Decrease of range.	
	Presbyopes.	Non-presbyopes.	Presbyopes.	Non-presbyopes.	Presbyopes.	Non-presbyopes.	Presbyopes.	Non-presbyopes.	Presbyopes.	Non-presbyopes.
Commencement of action	5·83 min.	7·33 min.	5 min.	4·33 min.	5·55 min.	9·83 min.				
Time of maximum action. .	20 ,,	15·67 ,,	22·22 ,,	26·17 ,,	15 ,,	20·83 ,,	51·87 min.	52·67 min.		
Amount of maximum action	3·58 D.	5·85 D.	10·38 D.	9·15 D.	. .	. .	9·24 D. or 2·16 of the normal range (4·28)	6·89 D. or 0·77 of the normal range (8·95)	1·09 D. or 0·33 of the normal range	2·26 D. or 0·25 of the normal range

II. *The Action of Pilocarpine on the Range of Accommodation of Emmetropes and Ametropes.*

We have always used a 1 per cent. solution of pilocarpine which was clear and transparent, and have applied it profusely to the eyes examined.

Case XVI.—C. P., æt. 19. A Hypermetrope on whose Eyes the Action of Eserine has been already recorded. *Right Eye.* Vertical Meridian only.

Time.	Near point.	Far point.
Before application..	9 cm.	−100 cm.
After application—		
5 minutes	9	−100
10 „	9	
15 „	9	
20 „	8·75	
25 „	7·25	200
30 „	7·25	100
35 „	6·5	75
40 „	6·75	96
45 „	6·5	250
50 „	6·75	Nearly normal.
55 „	7·25	
60 „	7	
70 „	7	
90 „	8	
120 „	8·5	
190 „	8	

In this case pilocarpine caused—

(1.) An approximation of the far point, which began at the 25th minute, reached its maximum at the 35th minute, and returned to its normal position at the 50th minute. The maximum approximation was equivalent to 2·33 D.

(2.) An approximation of the near point, which began at the 20th minute, reached its maximum at the 35th, and still existed at the 190th minute. The maximum approximation was equivalent to 4·27 D.

(3.) An increase in the range of accommodation, which began at the 15th minute, reached its maximum at the

60th minute, and still remained to a slight extent at the 190th minute. The maximum increase was 3·18 D., so that it was 0·26 of the normal range (12·11 D.).

This table and chart should be compared with Chart I.

Case XVII.—C. P. *Left Eye.* Vertical Meridian only. Very Profuse Application.

Time.	Near point.	Far point.
Before application ..	9 cm.	– 100 cm.
After application—		
5 minutes	9	– 100
10 "	9	– 100
15 "	7	150
20 "	6·5	100
25 "	5·5	82
30 "	6	88
35 "	6	88
40 "	6	200
45 "	6	250
50 "	5·5	Nearly normal.
55 "	5·5	
60 "	5·5	
65 "	5·5	
80 "	5·5	
95 "	6	
115 "	6·5	

In this case pilocarpine caused—

(1.) An approximation of the far point, which began at the 15th minute, reached its maximum at the 25th minute, and disappeared at the 50th minute. The maximum approximation was equivalent to 2·22 D.

(2.) An approximation of the near point, which began at the 15th minute, reached its maximum at the 25th minute, and still existed at the 115th to some degree. The maximum approximation was equivalent to 7·07 D.

(3.) An increase in the range of accommodation which was first manifest at the 15th minute, reached its maximum at the 55th minute, and existed to a considerable degree at the 115th minute, when the observations were discontinued. The maximum increase was equivalent to 7·07 D., that is 0·58 of the normal range (12·11 D.), so that at this time the total range was 19·18 D. (*See* Chart.)

CASE XVIII.—J. W. B. *Left Eye.* Action of Eserine on this Eye already recorded (p. 135).

Time.	Pupil.	Near point.	Far point.
Before application ..	4 mm.	11 cm.	−200 cm.
After application—			
5 minutes	4	11	−200
10 "	4	8·5	−200
15 "	3	9	73
20 "	2·5	7·75	60
25 "	2·25	8	45
30 "	2	8	43
35 "	2	7·5	41
40 "	2	8·25	70
45 "	2·25	8	63
50 "	2	8	70
55 "	2	8	85
65 "	..	8	200
70 "	..	8	Over 200 V. = $\frac{6}{6}$ partly.
130 "	3	9·5	

About the 20th minute a singular phenomenon occurred; the vision with the right eye = $\frac{6}{6}$, and with the left $\frac{6}{36}$; but if both eyes were opened together "the observed" could alternately see $\frac{6}{6}$ and $\frac{6}{36}$; if whilst the test types were being looked at by the left eye only the right eye was suddenly uncovered an appreciable time elapsed before perfect vision $\left(\frac{6}{6}\right)$ was obtained. The explanation of this phenomenon would seem to be that a reflex contraction of the right ciliary muscle, resulting from the contraction in the left eye caused by the action of the drug, had to be overcome by a volitional impulse before good distant vision could be obtained.

In this case pilocarpine caused—

(1.) An approximation of the far point, which began at the 15th minute, reached its maximum at the 35th minute, and disappeared at the 70th minute. The maximum approximation was equivalent to 2·94 D.

(2.) An approximation of the near point, which began at the 10th minute, reached its maximum at the 35th minute, and at the 130th minute had nearly reached its original position. The maximum approximation was equivalent to 4·24 D.

(3.) A contraction of the pupil, which began at the 15th minute, reached its maximum at the 30th minute, and had not disappeared at the 130th minute, when the observations were discontinued.

(4.) An increase in the range of accommodation, which began at the 10th minute, reached its maximum at the 70th minute, and still existed at the 130th minute. The maximum increase was 2·91 D., that is 0·3 of the normal range (9·59 D.), so that the total range was then 12·5 D.

Case XIX.—W. L., Myope, æt. 32. Vertical Meridian only.
Right Eye. Profuse Application.

Time.	Pupil.	Near point.	Far point.
Before application ..	3·5 mm.	10 cm.	23 cm.
After application—			
5 minutes	3·5	10	23
10 "	3·5	10	17
15 "	2·5	9·5	12
20 "	2	9	11·5
25 "	..	9·5	11·5
30 "	..	9	11
35 "	..	9	11
40 "	..	9	11
45 "	..	9·5	12
50 "	..	..	12
55 "	..	9	14
60 "	..	9·5	14·5
70 "	..	9·5	14
75 "	..	9·5	18
80 "	..	10	17
85 "	..	10	23
90 "	..	9·5	
100 "	..	10	23

In this case pilocarpine caused—

(1.) An approximation of the far point, which began at the 10th minute, reached its maximum at the 30th minute, and disappeared at the 85th minute. The maximum approximation was equivalent to 4·74 D.

(2.) An approximation of the near point, which began at the 15th minute, reached its maximum at the 20th minute, and disappeared at the 80th minute. The maximum approximation was equivalent to 1·11 D.

(3.) A contraction of the pupil, which began at the 15th minute, reached its maximum at the 20th, and was in that condition at the 105th minute, when the observations were discontinued.

(4.) A decrease in the range of accommodation, which was interrupted between the 85th and the 100th by an increase. The decrease reached its maximum at the 25th minute, and was then 3·82 D., that is 0·67 of the normal range (5·65 D.), so that at this time the total range was 1·83 D. The maximum increase was ·53 D. (*See* Chart.)

Case XX.—W. L., æt. 32. *Left Eye.* Profuse Application. The Action of Eserine on this Eye is already recorded (p. 138.)

Time.	Pupil.	Near point.	Far point.
Before application ..	3 mm.	9·5 cm.	20 cm.
After application—			
5 minutes	3	..	
10 "	3	8·5	17
15 "	2·5	8·5	13
20 "	2·5	9	13
25 "	2·5	8·5	13
30 "	2·5	8	13
35 "	2·5	8·5	13
40 "	2·5	8·5	14
45 "	2·5	8·5	17
50 "	2·5	8·5	17
55 "	2·5	9	17
60 "	2·5	9·5	22

In this eye pilocarpine caused—

(1.) An approximation of the far point, which began at the 10th minute, reached its maximum at the 15th minute, and disappeared at the 60th minute. The maximum approximation was equivalent to 2·69 D.

(2.) An approximation of the near point, which began at the 10th minute, reached its maximum at the 30th minute, and disappeared at the 60th minute. The maximum approximation was equivalent to 1·97 D.

(3.) A contraction of the pupil, which began within 15 minutes and reached its maximum at the 15th minute; it remained in this condition at the 60th minute, when the observations were discontinued.

(4.) A decrease in the range of accommodation, interrupted by an increase between the 5th and 10th and between the 45th and 50th minutes. The decrease reached its maximum at the 20th minute, and was 2·11 D., that is, 0·38 of the normal range (5·53 D.), so that at this time the total range was 3·42 D. The increase reached its maximum at the 10th, 45th, and 50th minutes, and was then 0·35 D., so that at those times the total range was 5·88 D.

Case XXI.—Action of Pilocarpine on Presbyopes. A. R., æt. 51. *Left Eye.* V. = $\frac{6}{6}$. Hm. 0·5 D. In the Right Eye, which possessed the same Refractive Character as the Left, Eserine produced a Great Increase in the Range of Accommodation as already recorded (p. 166).

Time.	Pupil.	Near point.	Far point.
Before application . .	5 mm.	63 cm.	−200 cm.
After application—			
5 minutes	5	63	−200
10 ,, ...	4	40	
15 ,, ...	3	30	175
20 ,, ...	3	30	125
25 ,, ...	2·5	25	200
30 ,, ...	2·5	30	Much receded.
35 ,, ...	2·5	30	
40 ,, ...	2·5	28	
45 ,, ...	2·5	26	
50 ,, ...	2·5	32	Distant vision not quite so good as before application.
55 ,, ...	2·5	34	
60 ,, ...	2·5	33	
65 ,, ...	2·5	30	
70 ,, ...	2·5	30	
75 ,, ...	2·5	30	
80 ,, ...	2·5	33	
85 ,, ...	2·5	33	
90 ,, ...	2·5	33	
95 ,, ...	2·5	30	
120 ,, ...	2·5	35	
130 ,, ...	2·5	35	

In this case pilocarpine caused—

(1.) An approximation of the far point, which began at the 15th minute, reached its maximum at the 20th minute, and disappeared at the 50th minute. The maximum approximation was equivalent to 1·3 D.

(2.) An approximation of the near point, which began at the 10th minute, reached its maximum at the 25th minute, and existed to some extent at the 130th minute, when the observations were discontinued. The maximum approximation was equivalent to 2·41 D.

(3.) A contraction of the pupil, which began at the 10th, reached its maximum at the 25th minute, and remained in this condition at the 130th minute.

(4.) An increase in the range of accommodation, which began at the 5th minute, reached its maximum at the 45th minute, and still existed to a considerable degree at the 130th minute. The increase at its maximum was 2·26 D., that is, 1·08 of the normal range (2·09 D.), so that at that time the total range was 4·35 D.

Summary.

A profuse application of a 1 per cent. solution of pilocarpine to these healthy emmetropic and ametropic eyes caused—

(1.) An approximation of the far point, which began from the 10th to the 25th minute, reached its maximum from the 15th to the 35th minute, and disappeared from the 50th to the 85th minute. The maximum approximation was equivalent to from 2·22 D. to 4·74 D.

(2.) An approximation of the near point, which began from the 10th to the 20th minute, reached its maximum from the 20th to the 35th minute, and disappeared in from 60 to 80 minutes and later. The maximum approximation was equivalent to from 1·11 D. to 7·06 D.

(3.) A contraction of the pupil, which began from the 10th to the 15th minute, and reached its maximum from the 15th to the 30th minute.

(4.) An increase of the range of accommodation, which began from the 10th to the 15th minute, reached its maximum from the 10th to the 90th minute, and amounted to from 0·35 D. to 7·07 D. In two cases this increase was preceded by a decrease, which reached its maximum at the 20th and 25th minutes, and amounted to 2·11 D. and 3·82 D. The normal range varied from 2·09 D. to 12·11 D.

Taking the average of these results, it is seen that pilocarpine caused—

(1.) An approximation of the far point, which began at the 15th minute, reached its maximum at the 26·67 minute, and disappeared in 60·83 minutes. The maximum approximation was equivalent to 2·7 D.

(2.) An approximation of the near point, which began in 13·33 minutes, reached its maximum in 28·33 minutes, and returned in 70 minutes. The maximum approximation was equivalent to 3·51 D.

(3.) A contraction of the pupil, which began at the 13·75 minute, and reached its maximum at the 22·5 minute, and disappeared within 48 hours.

(4.) An increase in the range of accommodation, which began in 11·25 minutes, and reached its maximum in 60·9 minutes. The maximum increase was equivalent to 2·72 D., whilst the average normal range was 7·84 D., that is, the proportion of the increase to the normal range was 0·36 D.

The decrease of the range which occurred in two cases was at its maximum at the 22·5 minute, and was then equivalent to 2·96 D.

Tweedy (12) seems to have been the first to draw attention to the influence of extract of jaborandi on the eye; he states that after its local application there occurred "tension of the accommodative apparatus of the eye with approximation of the far and near points of distinct vision." In his case the maximum effect was noticed in 40 minutes, and the effect had quite passed away in 90 minutes, but he does not refer to the influence on the range of accommodation, nor is it possible to estimate it accurately from his figures.

George (13) applied a 10 per cent. glycerine extract to his eyes, and found that the far and near points were approximated, and that the maximum approximation of the near point was reached in from one-half to five-fourths of an hour, but apparently he never observed the change in the range.

A. Weber (22) does not refer to its action on the accommodation apparatus.

Fronmüller (23) states that the action of jaborandi and pilocarpine is identical.

Königshofer (33) applied extract of jaborandi locally, and could observe no action on the pupil or accommodation, but local application of pilocarpine caused "einer Anspannung, die sich nach und nach steigert, um nach $\frac{3}{4}$ Stunden einen Grad zu erreichen, zu dessen Ausgleichung ungefähr ein Convexglas von 40 Zoll Brennweite erforderlich war. Gleichzeitig rückt der Nahepunkt um ca. 1″ herein. Hand in Hand mit dieser Hereinrückung der Fern- und Nahepunkte geht eine hochgradige Verengung der Pupille." . . . "Die Accommodationsanspannung gleicht sich nach $1\frac{1}{4}$ bis $1\frac{1}{2}$ Stunde wieder vollkommen aus." The myosis, however, lasted about one day.

Scotti (28) says that the far point was not very much approximated by pilocarpine, but neither he nor Königshofer draws attention to any alteration in the range of accommodation which it produces.

Just (35) simply says "und einen starken Reiz für die Accommodation darstellt."

Doyer (36) also does not refer to any alteration of range.

Albertoni (34) applied to the eyes a few drops of a 1 or 2 per cent. solution of pilocarpine, and found "während der ganzen Dauer der Myose wird das Auge in der That myopisch; der Nahpunkt ist ungefähr um die Hälfte näher ans Auge herangerückt (von 14 auf 7, von 16 auf 8 cm.), der Fernpunkt ist ebenfalls sehr stark genähert und fällt beinahe mit dem Nahpunkt zusammen, so dass um die ursprüngliche Schweite wieder herzustellen starke Negativlinsen erforderlich sind. Ja die Annäherung des Fernpunktes übertrifft immer an Dauer und Intensität diejenige des Nahpunktes. Hat die Myose aufgehört, so ist der Accommodationskrampf durchaus noch nicht verschwunden, sondern blos schwächer geworden, denn der

Fernpunkt ist noch immer sehr stark genähert. Indem der Accommodationskrampf sich nach und nach abschwächt, hört er erst ungefähr 4—5 Stunden nach der Einträufelung gänzlich auf, nämlich 2—3 Stunden nach Beginn der Mydriase." Nitrate and hydrochlorate of pilocarpine act in much the same manner. From this it would seem that he caused a decrease of the range by local application, and that the far point did not recede to its normal position for several hours.

Lewin (38) says that by subcutaneous injections the eye was made myopic, and whilst the far point was much approximated the near point was more powerfully affected. Local applications caused much the same thing.

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Chart of Case 1.

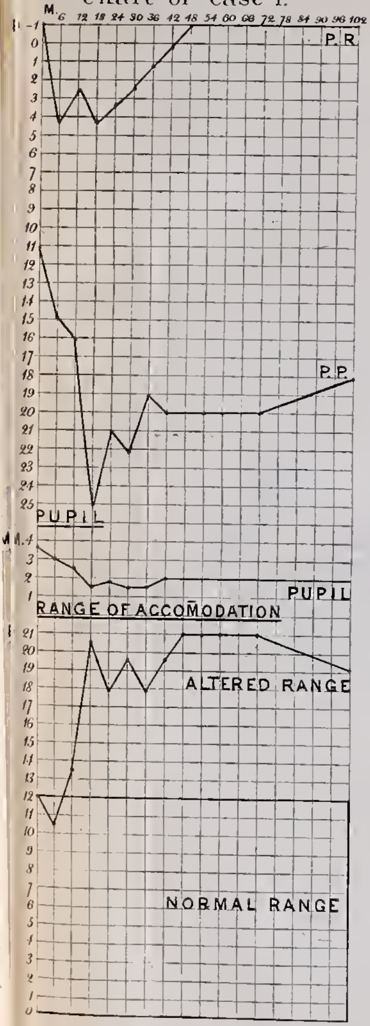


Chart of Case 4.

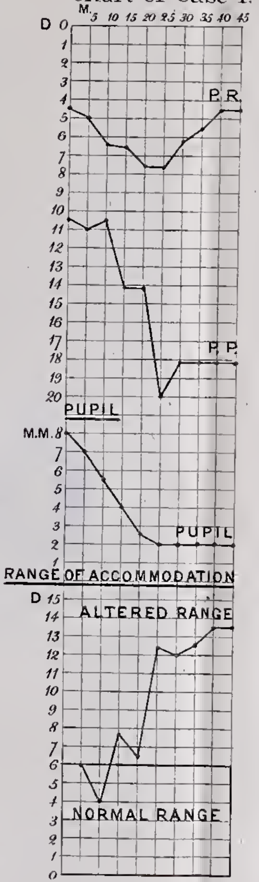


Chart of Case 7.

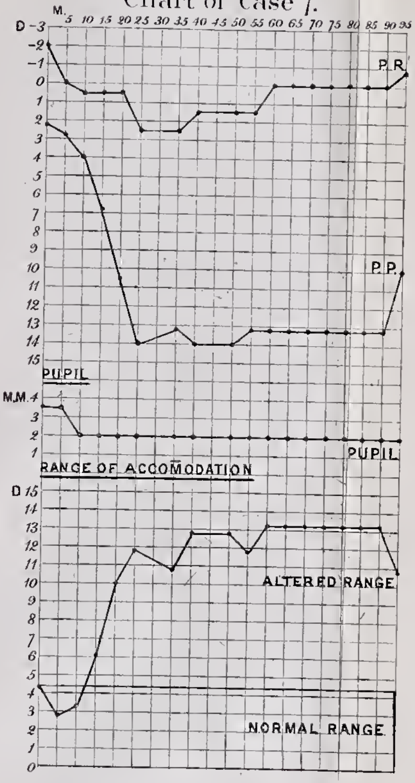
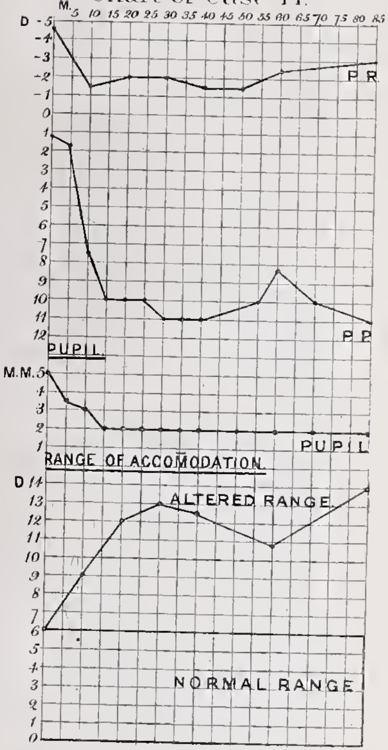


Chart of Case 14.



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ROYAL COLLEGE O[illegible] OF ENGLAND
[illegible] 24

Chart of Case 16.

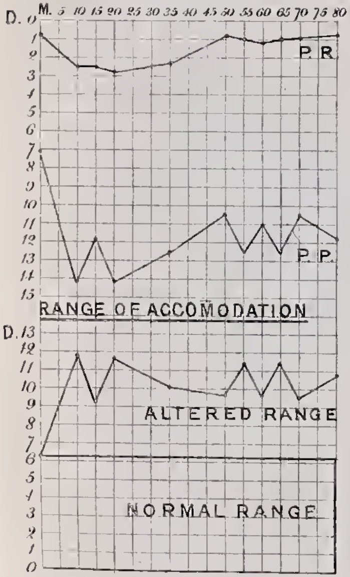


Chart of Case 17.

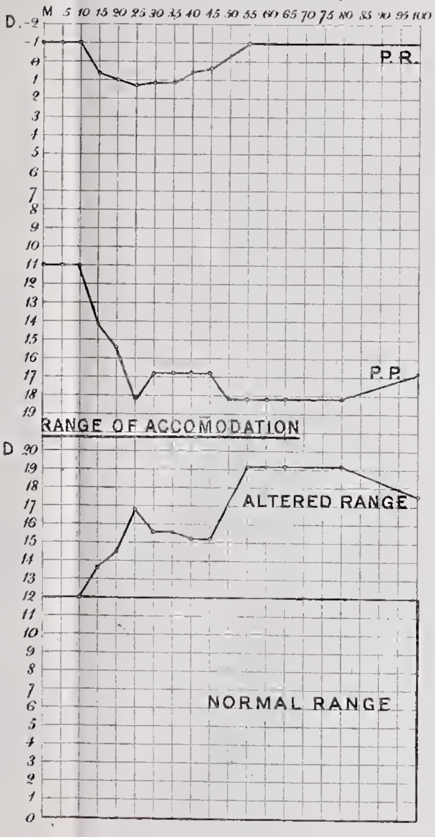


Chart of Case 18.

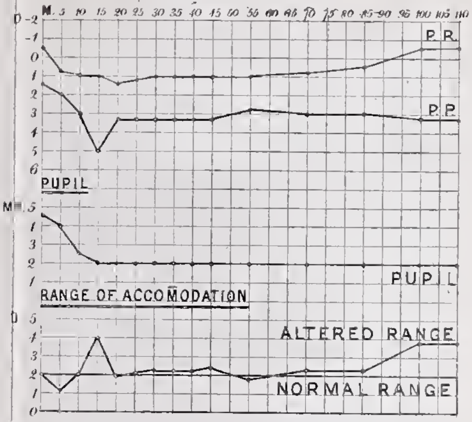
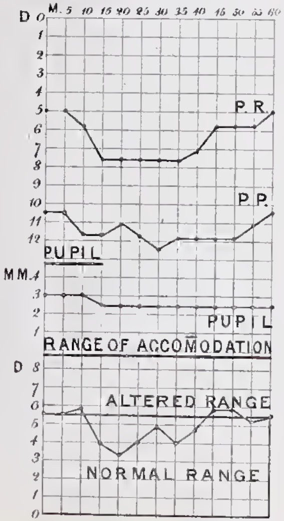


Chart of Case 19.



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COLLEGE OF SURGEONS
24

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